

JUNE 1953

Chemical Engineering Progress

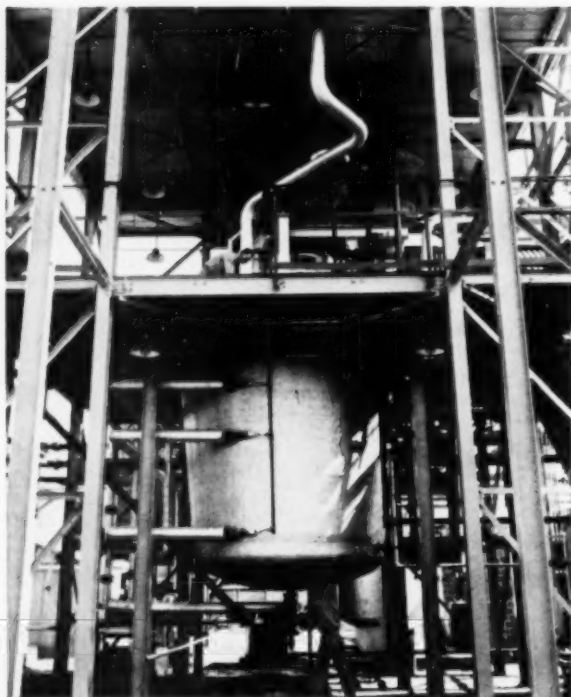
PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

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Chemical Engineering Progress

JUNE, 1953

Volume 49, No. 6

Editor: F. J. Van Antwerpen

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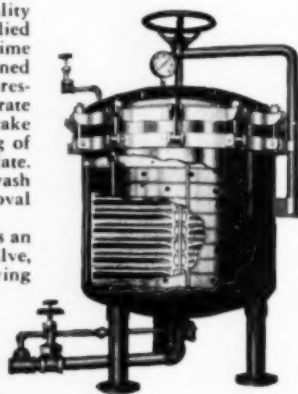
Complete filter cake stability, and the ability of the Sparkler horizontal filter plate to accommodate any combination of filter media and filter aid with maximum efficiency is the reason Sparkler filters meet the most exacting requirements for fine filtering.

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NOTED AND

QUOTED

Our Hungry Engineers

The constant and insistent need that engineers feel for any scrap of fact from which they may predict natural phenomena tends to develop a hunger for anything that even resembles a fact. This in turn may lead to a wolfish and gluttonous attitude, a gobbling up of every statement or opinion, figure or formula, indiscriminately and incessantly. The result is often intellectual autointoxication from "hunks and gobs" of unselected, undigested and indigestible material.

Hardy Cross

Engineers and Ivory Towers

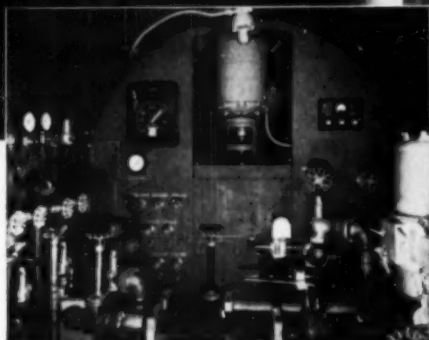
Directed Research

Within the short space of ten years we have witnessed the phenomenon of the science departments of our universities gradually being drawn into research and development for practical ends. The problem is not so acute perhaps if the research undertaken is reasonably compatible with the research activities of the universities and can be accomplished without major dislocations in either the research or teaching programs. In a number of instances, however, the demands upon universities for this kind of work have become so numerous and the magnitude of the work so great that it has been deemed necessary to separate this type of activity from the educational core of the university. Some laboratories for this purpose are even apart in geographic location from the university proper. This arrangement has the advantages of separating work of a practical nature from the educational program which is largely concerned with fundamentals of science. It also makes possible easier recruitment of personnel, and a special administrative office to handle outside business. However, it creates other problems, chief among which are: the employment of substantial numbers of research scientists and technicians without teaching or educational responsibilities; the diversion of graduate students from their normal study into special research activities related to defense or other Federal interest; and a host of new problems related to academic salary and tenure, summer work, and possible competition with industry. The last can arise from a feeling that it is easy for such a research establishment also to handle industrial research problems.

What to do about the situation has become a major question. Obviously the

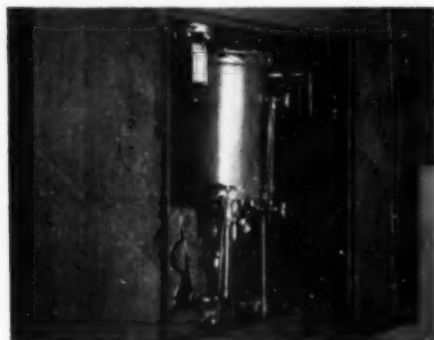
Turn to page 8

RUSH! 12 TONS LIQUID OXYGEN



CONTROL PANEL
Hofman Liquid Oxygen Transport Unit

Note the accessibility of all instruments on this control board. At top center is the motor driven LO_2 Pump, for the transfer of liquid from the oxygen container. Can handle 100 to 150 gallons per minute against a head of 40 psig. Operates on a minimum of 15 psig suction head. Liquid level gauge is to the right.



VACUUM PUMP

This electrical motor driven vacuum pump permits evacuation of the insulation space. A removable filter prevents particles of insulation or other foreign matter from entering the pump mechanism.



Hofman Laboratories' new semi-trailer mounted Liquid Oxygen and Nitrogen Transport Unit is an important contribution to the nation's defense program as well as to thousands of industrial laboratories engaged in extreme low temperature work. In this 8 to 12 ton capacity mobile unit Hofman has met ever-increasing demands for the storage, transfer and transport of huge quantities of liquid oxygen while maintaining a minimum of evaporation loss under all conditions. The equipment is designed to withstand severe shock loads, even when operating in the roughest terrain.

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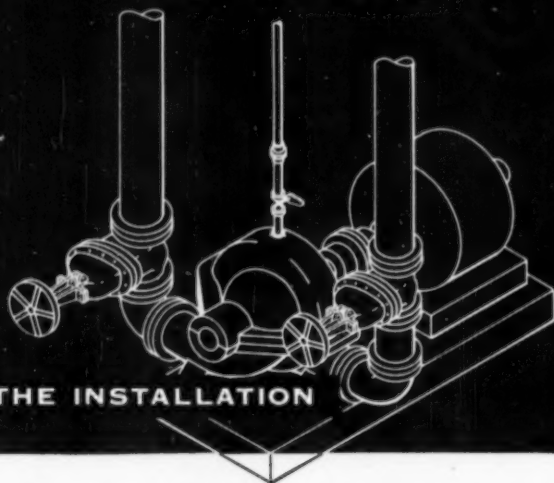
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Originally the Crane valves were installed on belt-driven pumps when the plant was built in 1903. In 1952, the old pumps were replaced. Nearly all the Crane valves were found in good condition and put right back in service on the new pumps.

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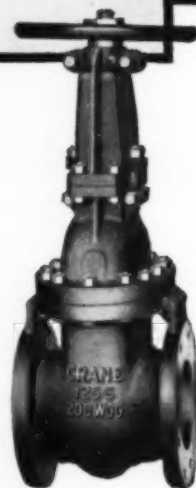
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Here is today's model of these "50-year service record" Crane 125-pound iron wedge gate valves. Still made to the most rigid quality standards, these modern valves keep building unusual performance records in every industry. They come in patterns for every need. See your Crane Catalog or your Crane Representative.

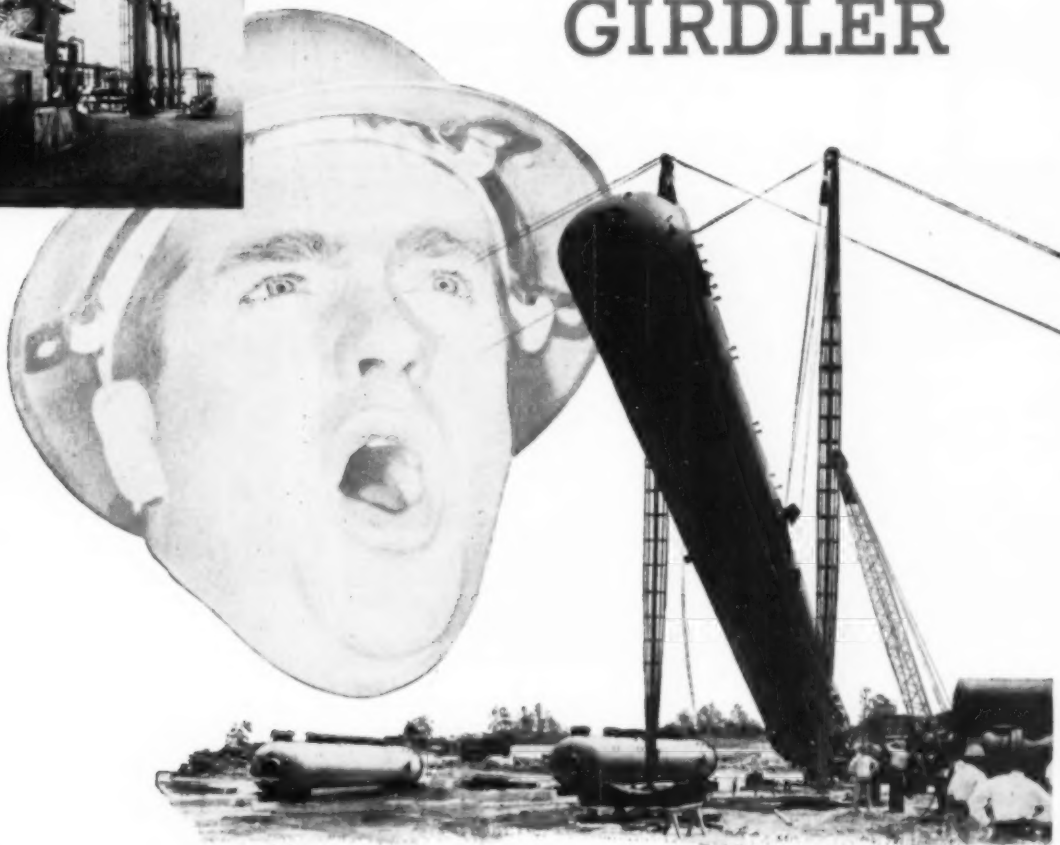


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Air view of West End Chemical Co. buildings. Annual production capacity is 200,000 tons of soda products and borates. ▶



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national security comes first, and all of the research and development that can effectively contribute to that end should be done.

Nevertheless it may be pertinent to ask whether, in fact, the huge sums presently being appropriated directly for military research and development have taken adequate account of the need for advancing the frontiers of science and for training young scientists and engineers. It may also be pertinent to ask whether a greater effort in the less expensive basic stages of research may not lead to reductions of effort in the far costlier stages of development and prototype construction. Both the universities and the Federal Government should critically examine the question whether all the research that the universities are being asked to do is properly the kind of research that belongs in the universities, or whether some of it might not more properly be carried on in Service laboratories or by industrial organizations.

Alan T. Waterman
National Science Foundation

The Role of Science

Contrary to a widely held notion, science, both in its results and in its method, presents a particularly fruitful field for the discovery and development of moral and spiritual values, especially because it plays such a dominant part in modern life. Not only does science as a method involve ethical qualities of the highest order, but its results have far-reaching social, moral, and spiritual consequences.

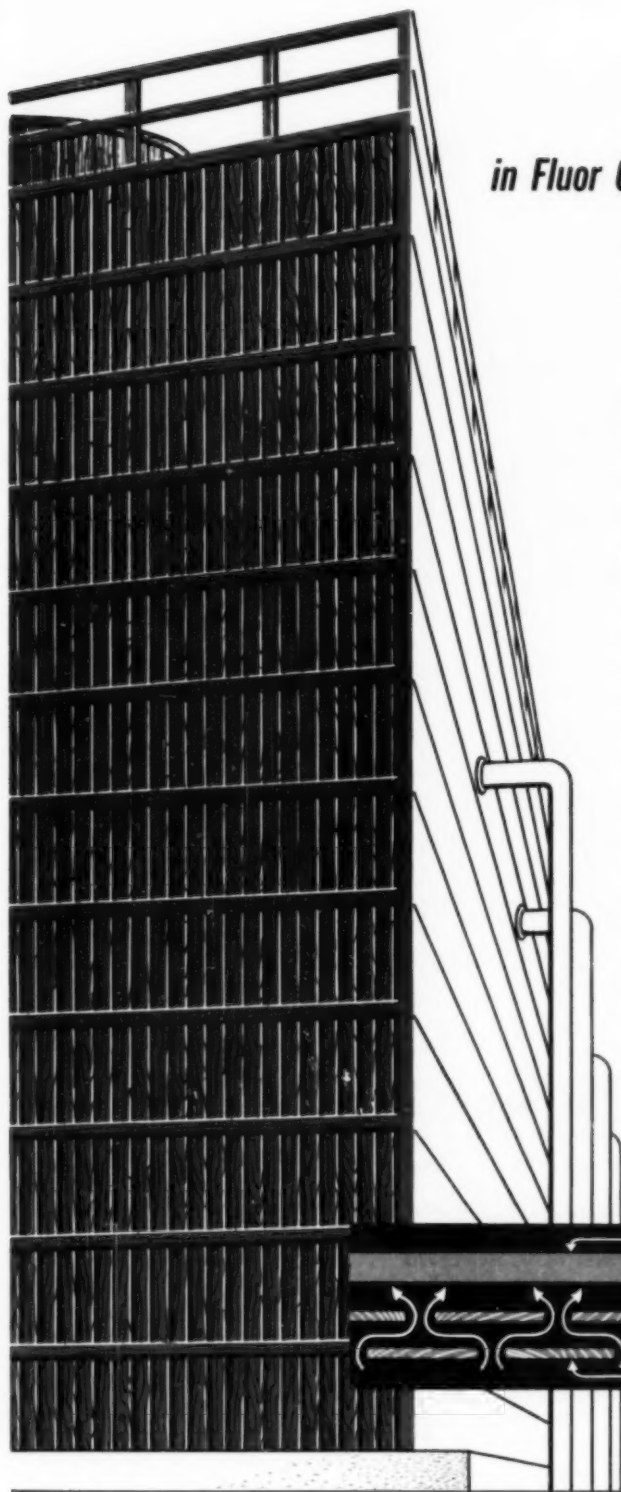
1. Science teaching should lay the foundation for cause-effect thinking and should replace superstition with fact. . . . Its method gives an opportunity for the development of reflective thinking, intellectual honesty, open-mindedness, and suspended judgment. . . . Laboratory projects offer rich opportunities for co-operation, courtesy, initiative, and personal integrity. . . . Teachers should emphasize the fact that science exists for man, not man for science.

2. In addition to regular classroom and laboratory procedures, field trips are productive of value appreciation. Among the wide variety of field trips may be mentioned . . . visits to industrial plants, observation of the causes and results of erosion, visits to engineering projects. . . .

3. A fruitful source of values in the field of science is the study of the lives of great scientists and their achievements. . . .

W. C. Bower
Moral and Spiritual Values in Education

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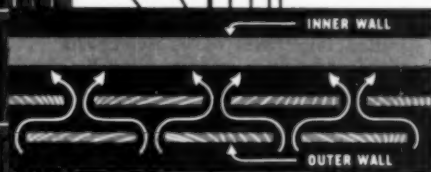
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adds protection and lasting good looks

Double wall construction provided on Fluor induced-draft cooling towers has a double meaning—protection and beauty. The outer wall consists of a double row of vertical Redwood battens which are located four inches out beyond the inner wall. This protective casing is neat, symmetrical, eye appealing and greatly enhances the beauty of a cooling tower. It weathers uniformly. Unsightly stains and blemishes that mar a cooling tower's appearance are impossible. The equally spaced rows of battens also permit air circulation around walls to prevent dry rot, algae growth and other blights that attack unventilated cooling tower walls.

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Top view of double wall. The uniform spacing of vertical battens is not for the sake of appearance alone. Air is permitted to circulate between the aerators to prevent dry rot and living organisms from attacking tower walls.

BE SURE WITH

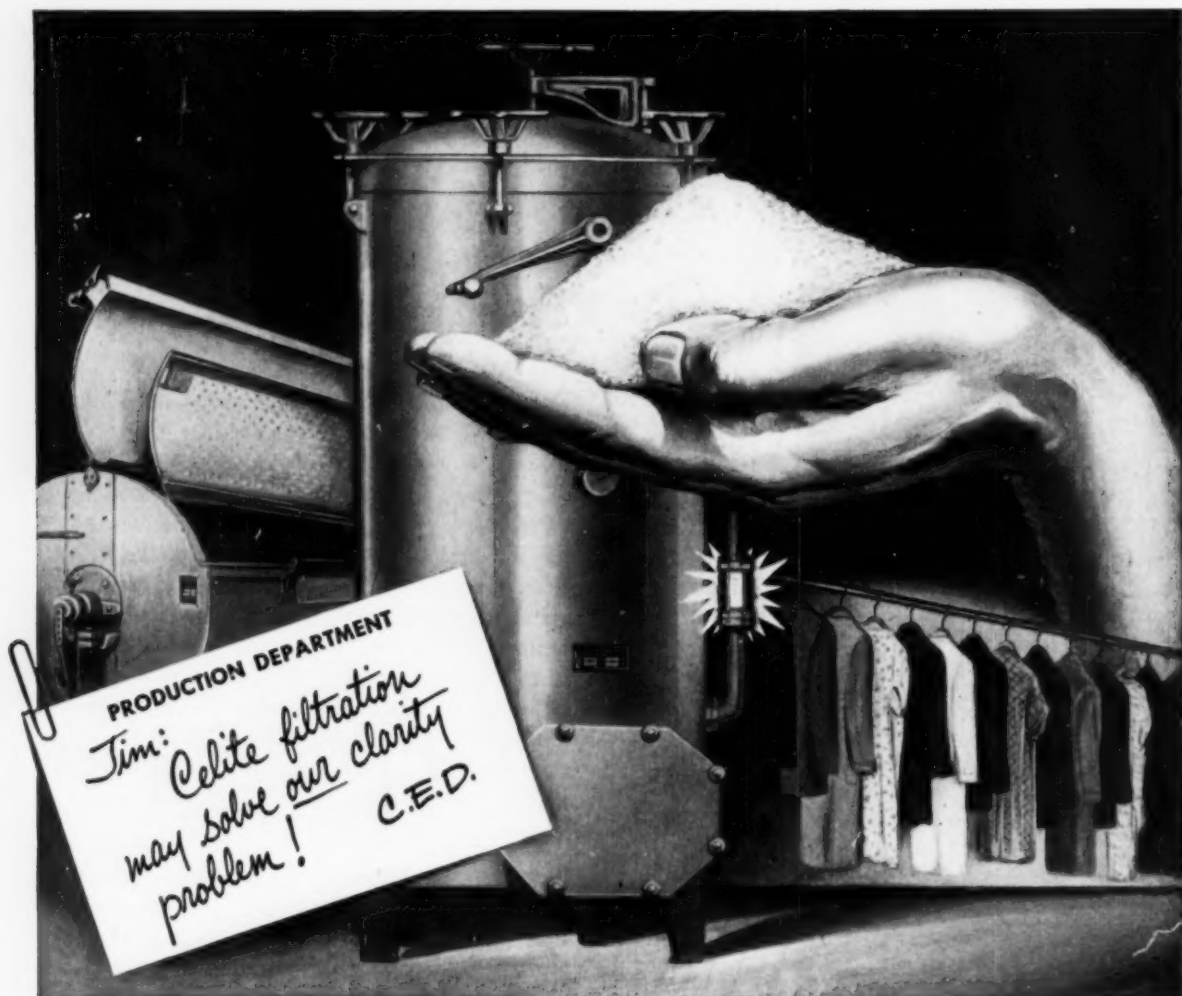
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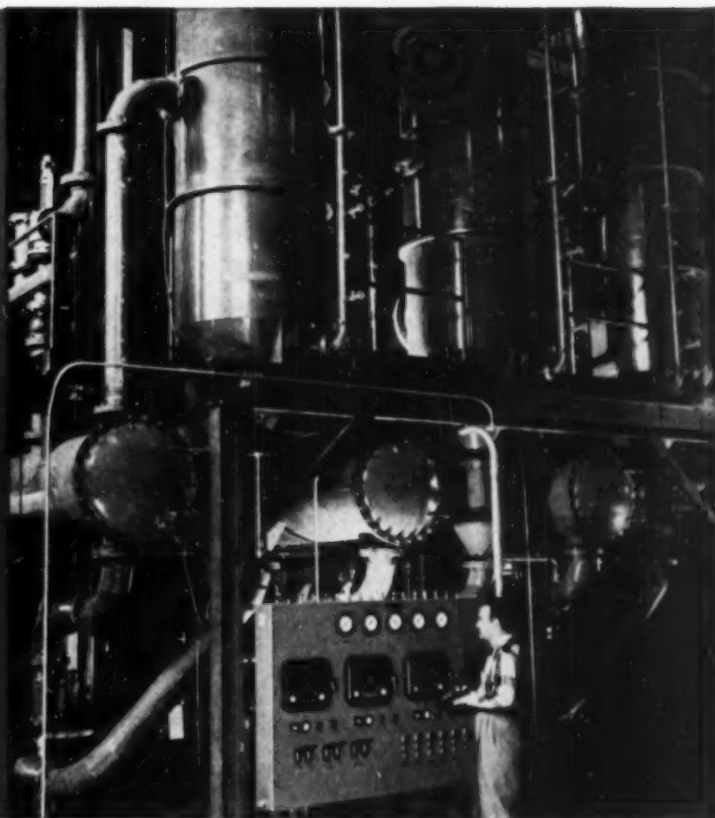
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Believing Is Not Seeing

Socrates defined the philosopher as a thorn in the flesh, and nobody is a creative thinker unless continuously he has a thorn in his flesh, that is, unless he is disturbed by something. The thick-skinned people do no creative thinking; to them everything is understood, they have no problems, nothing baffles them. . . .

What should we conceive our world to be if we restricted ourselves to so-called pure fact, if everything in which we believe were reduced to what we directly inspect? Many people suppose that science restricts itself to directly observed facts. Yet nobody has ever directly inspected an electron. We all believe that this apparently empty space between us is filled with electromagnetic waves traveling at approximately 186,000 miles a second. Nobody can claim directly to see these waves. Most of our scientific knowledge is knowledge of entities and processes and relations that are not given as pure fact but are only inferred. It is precisely for this reason that scientific knowledge of the western type is imaginative and creative in a way in which I believe that knowledge of classical Asia is not.

F. S. C. Northrop

The Nature of Creative Thinking

Superman

Most people are not aware of it, but the engineer is also a political, economic as well as social force. . . . He is the fellow who really dissolves monopolies, redistributes the wealth, and dismantles political platforms. Over our history, one generation after another, men have been selected to office by being sequentially "agin" the monopoly of canals, or railroads or anthracite coal or kerosene oil or slums or private development of water power. There were no doubt great evils. But I ask you who really remedied these evils? It was the engineer. He upset the canal monopoly with the railways; he upset the railways with the automobile, the airplane and the pipeline. He upset the anthracite monopoly with coke; he upset the monopoly in kerosene oil with the electric light. He assured that most of the streams would remain as scenery by making cheaper power with steam. Who makes possible the escape from the slums? It is the engineer with his parkways, his bridges, his satellite towns. Who provided leisure for the housewife to play canasta and attend political meetings? It was the engineer with his household gadgets.

Herbert Hoover

The Journal of Engineering Education

**Electrolytic Aids to
CHEMICAL PROCESSING PROGRESS**

The newly designed, high capacity Hooker Type S-3 cells are playing an increasingly important part in the production of "workhorse" chemicals for the process industries.

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4

reasons why Trane dry-type fluid coolers last longer

1

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A wide variety of types of metals are available for highly corrosive applications. Coils can be supplied in combinations of cupro nickel, admiralty, red brass, copper, aluminum, monel, steel, stainless steel and many other special metals. TRANE engineered products have solved corrosion problems of all types, yet obtained maximum heat transfer and maximum life from the fluid circuit.

2

Permanently bonded fins

In constructing the Extended Surface Coil—heart of the fluid cooler—TRANE bonds fin to tube *mechanically*. This bond is as permanent as the metals that form it and as strong as though fin-and-tube were one. Heavy support plates are used to reinforce and protect the coil and prevent tube sagging. And the exclusive TRANE Guide Flange cradles the coil to permit expansion within casing.

3

Extra-rugged construction

Framework of the TRANE Fluid Cooler is so strong it can be used for stationary or portable installation *without additional bracing*. Its simple structural design permits fastest possible erection. Yet it is more than strong enough to support core and accessories and withstand wind and shock load. Finish on the TRANE Fluid Cooler is a rubber-base paint that's completely weatherproof.

4

Freedom from vibration

TRANE Fluid Coolers run smoothly . . . quietly. They stay sound and tight longer because TRANE engineers have virtually eliminated the causes of vibration. Here's how: The variable-pitch fans are dynamically balanced. Solid, oversized fan shaft is firmly mounted in giant thrust bearings. Drive components are aligned at the factory and shipped assembled. Orifice ring is designed to *match* the fan.



Trane Dry-Type Fluid Coolers can be used profitably in hundreds of ways. Series GC for vertical discharge (shown above) is made in 6 regular sizes with fan diameters ranging from 72" to 144".

TRANE

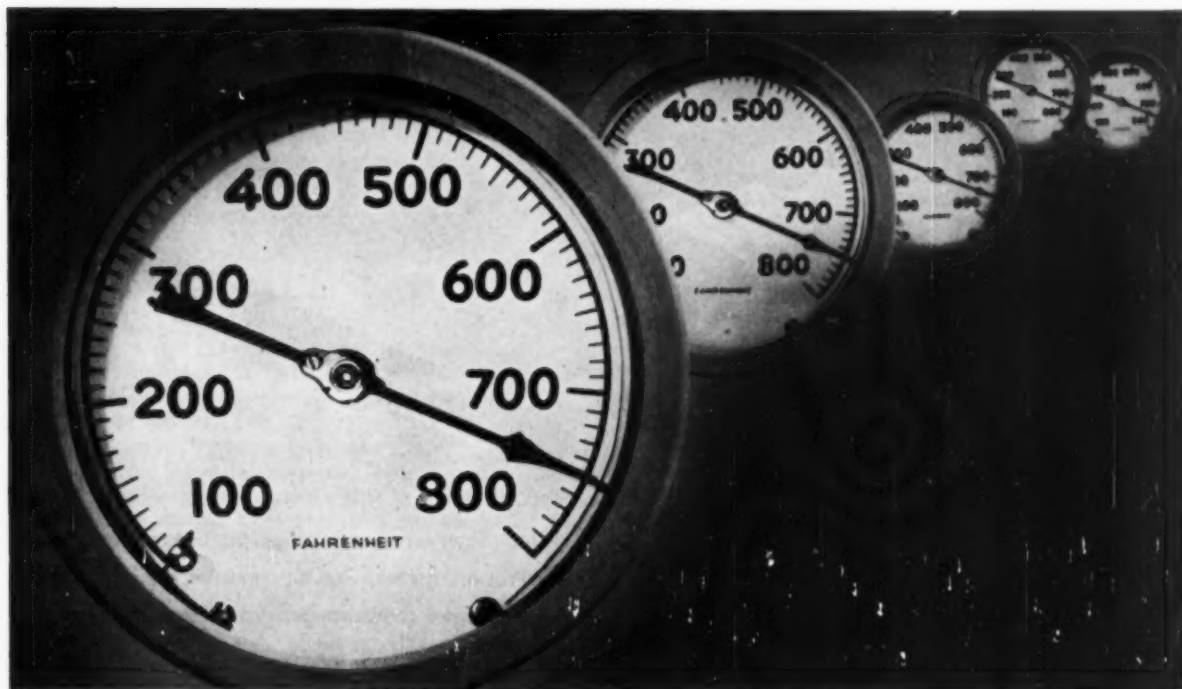
pioneers in the science of heat exchange

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MANUFACTURING ENGINEERS OF HEATING, VENTILATING, AIR CONDITIONING AND HEAT TRANSFER EQUIPMENT

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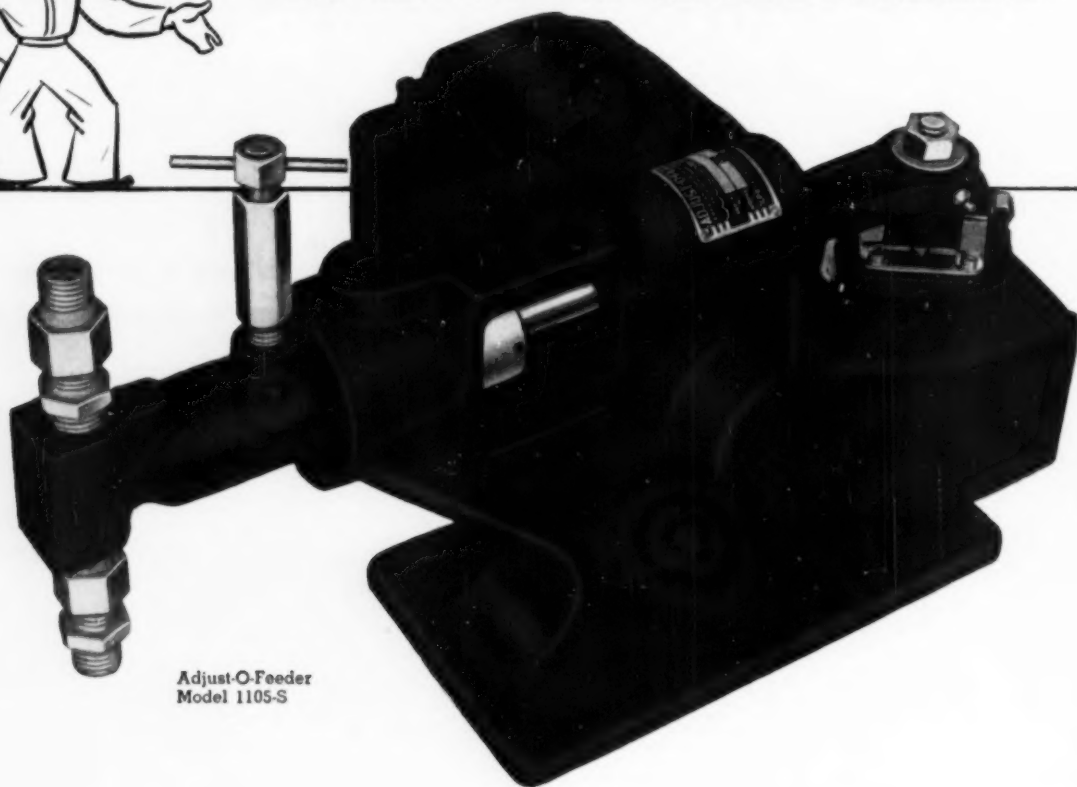
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Adjust-O-Feeder
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Built-in standard motor — no separate gearbox or couplings.
Built-in oil-enclosed gear reducer.
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One-piece Meehanite iron frame for positive alignment of all moving parts.
Double check valves on suction and discharge easily removable.

This new, compact proportioning pump, by %Proportioneers, Inc.%, is inexpensive and meets most requirements for a low capacity, medium pressure chemical feed pump. The standard Model 1105-S has a capacity range from 1 to 10 GPH and will discharge against pressures up to 650 psig. For lower feeds, the unit is available with a range of from 0.5 to 5 GPH. Complete and self-contained, Model 1105-S weighs less than 100 lbs. and is ready to operate.

Ask for Bulletin 1105

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Write to %PROPORTIONEERS, INC.%, 419 Harris Ave., Providence 1, R. I.

Technical service representatives in principal cities of the United States, Canada, Mexico and other foreign countries.

Opinion and comment

AN ANSWER REQUIRES QUESTIONS

In almost every talk we give, and in many conversations we have with our members on the problems of publishing an engineering magazine, the question is invariably asked, "Why don't you sell more advertising?" It is a good question, one we like to try to answer, for it stems from the realization that to provide the chemical engineering profession with the kind and volume of articles it needs, Chemical Engineering Progress must have revenues other than our subscription fees.

Perhaps this month is as good a time as any to go into the problem of why we don't sell more advertising," and tell our members just what is involved. It is especially apt also, for in the news section we have begun a new reader inquiry service on advertised products.

First and foremost, advertising is placed in a magazine such as ours to sell a product or service. Advertising gets itself into the magazine through a business approach by our advertising salesmen based on the service we render month after month to the chemical engineers of the nation. Their sales efforts are backed up to the limit of our resources with direct mail, our own advertising in marketing magazines, and other normal sales aids.

This has worked up to a certain point. "C.E.P." began its life in 1947, and has made substantial headway in the number of advertising pages it carries. During the past twelve months it has carried more than two and one-half times the amount of advertising carried in its first year of publication.

But even though we are publishing more than ever before, developments and techniques in our field are booming, and pressures for publication build up quickly and powerfully. It is our opinion that chemical engineering, as a profession, is being limited by its inadequacy to publish sufficient significant material promptly. To do the needed job means more money, and to get money means more dues, a philanthropic gift, or more advertising.

More dues at best would be a temporary solution, and this is probably more apparent to an editor because of the advantage he has in seeing the amount of engineering literature which could be encouraged into publication if the proper outlets were available. Philanthropy is likewise a thin hope, for unfortunately chemical engineering is growing up in a time when large personal fortunes are either not being created or are being drained away in taxes. The only permanent solution to the problem of an adequate chemical engineering literature is the creation of magazine properties which, through their appeal to the reader, month after month, and year after year, attract the best in readers and in advertising.

This we are striving to do, and while the distance to the goal is great, we believe we are on the right path. But the selling job has its difficulties. We mentioned before that advertising is placed in a magazine to sell something. This is true, and it puts our readers in the position of being double customers; they are the customers of the editorial program;

they are also customers of the advertising messages. And the appeal of the one directly influences the other, for one of advertising's standard measures of a magazine's value is reader response to the advertising message. The new emphasis on inquiries in our field has given rise to services in the magazines designed to make the asking of a question about a product a simple thing, services such as our Data Service and the new service on our advertisers' products.

So when it comes down to the final analysis of which magazine is to receive advertising support, the advertising buyer uses the same techniques as the engineer—he often coldly calculates the book best for him as far as cost of inquiries and expected sales is concerned.

But books such as ours are at a disadvantage when it comes to competitive selling. We publish the difficult—the solid material which requires study but which at the same time is so essential to the success of the chemical industry that to cease its publication would invite stagnation and ultimately disaster for us as a field and as a profession. We publish heat transfer equations secure in the knowledge that the engineer, who understands them and uses them, is the man who specifies the equipment which is ultimately purchased. We know when we print new studies on distillation columns that it is only a matter of time before the equations are translated into production equipment hundreds of feet high. Our studies reach men who not only have the education to understand, but who also have the responsibility finally to pick and choose locations, new materials, products, equipment, and markets. We know that our readers exert a powerful buying influence. We further know that the chemical engineers who belong to the American Institute of Chemical Engineers are the best engineers in the profession, and as we visit with them across the country, we are impressed with the work they do—the plants they manage, the equipment they buy, and the easy familiarity they show with production tools and applications.

"C.E.P." has an extremely high home-readership. Since 12,000 of our 17,000 readers are members of the A.I.Ch.E., and since such membership is a personal affair, magazines are usually sent to the home. Hence, when our typical reader sees something of interest to him, he is away from the routine of the office, and the ability to write a letter of inquiry easily.

So, since inquiries have assumed such importance in selling advertising, and since our readers buy so much in equipment, services, and chemicals, it seemed logical to the editor and the sales force to tap, in an easy fashion, the economic influence of our chemical engineering membership. We hope that you, as an important member of industry's team, use these inquiry services for your legitimate information needs. By so doing the profession is encouraged, and the vital literature is being served.

Here is the answer then to the question why don't you sell more advertising? In short, it is not only dependent on a good selling job, but it requires evidence from the reader that our editorial content is to his best interest and interests.

INTALOX SADDLE PACKING DISTILLS 10% MORE CHARGE IN 10% LESS TIME

Field experience is consistently bearing out earlier test data reflecting the greater efficiency of Intalox Saddle Packing. But it is infrequent to have such excellent comparative data as that furnished us by a major manufacturer of organic chemicals.

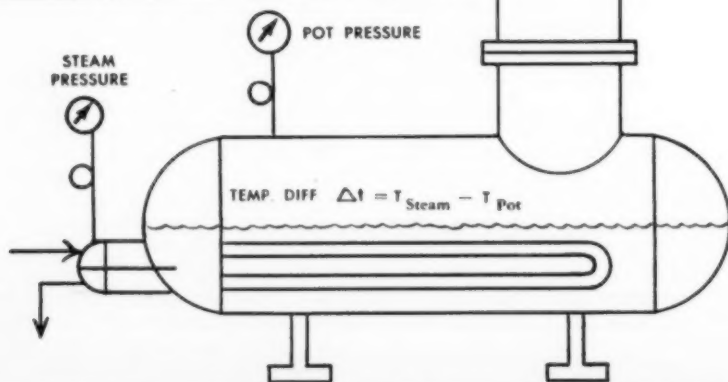
Two column stills with identical column and condenser characteristics distilled the same materials side by side, under carefully controlled duplicate conditions. The Towers were 19" ID with a packed height of 32'. Steam pressure in the coils was 100 psi-g in both cases. The only difference was that Tower "A" was packed with 1" chemical porcelain Intalox Saddles, Tower "B" with 1" chemical porcelain Berl Saddles.

Tower "A" handled a 10% greater charge in 10% less time than Tower "B" with product specification equal.

The substantially lower pressure drop through Intalox Saddles results from the unique, patented design, which provides a greater degree of randomness in packed beds. No two pieces can fit exactly into the other. Pattern packing, nesting, over-lapping and "blocked" areas are held to a minimum. The greater total surface area of Intalox Saddles is thus accompanied by greater available surface area to liquor and gas. Greater operating economies, higher product yields, and favorable HTU factors, establish Intalox as the preferred packing.

Here are the comparative figures

Tower	Type of Packing	Pot Pressure mm. Hg.	Condenser Pressure mm. Hg.	Pressure Drop Δp mm. Hg.	Pot Temp. °F	Steam Temp. (100 psi-g = 338°F) minus Pot Temp.	Relative Temp. Driving Force, as based on Berl Saddles
PRODUCT No. 1							
A	1" Intalox Saddles	22	4	18	234°F	$\frac{338^\circ - 234^\circ}{104^\circ}$	1.46
B	1" Berl Saddles	43	6	37	267°F	$\frac{338^\circ - 267^\circ}{71^\circ}$	1.00
PRODUCT No. 2							
A	1" Intalox Saddles	28	5	23	230°F	$\frac{338^\circ - 230^\circ}{108^\circ}$	1.46
B	1" Berl Saddles	42	6	36	264°F	$\frac{338^\circ - 264^\circ}{74^\circ}$	1.00



INTALOX OFFERS:

- Lower Pressure Drop
- Higher Flooding Limits
- More Surface Area
- Greater Free Space
- More Area Accessibility

166-4

U. S. STONEWARE

AKRON 9, OHIO

Performance of a Pulse Extraction Column

R. M. Cohen and G. H. Beyer Iowa State College, Ames, Iowa

Continuous liquid-liquid extraction processes have been used industrially to great advantage as a means of chemical separation and purification where operations such as distillation or adsorption are impractical.

Equipment design for continuous countercurrent extraction is largely based upon various methods for obtaining a high interfacial area between the two liquids contacted. Greater efficiency or improved mass transfer is usually achieved by increasing the degree of mixing of the two phases. In spray columns, this is brought about by dispersing one liquid as droplets in the second liquid, while packed columns increase the turbulence of flow and the film surface area by utilizing packing. Mixer-settler equipment takes advantage of stagewise contact in alternate mixing and settling units, whereas perforated-plate towers are essentially vertical mixer-settlers in which successive dispersion and coalescence are accomplished by perforated plates. In the latter, as well as in spray, packed, and baffle-type columns, low stage efficiencies are encountered because of the poor mixing resulting from counterflow of the two phases past each other by virtue of their density difference alone.

Recently various mechanically powered devices having higher throughputs and efficiencies than conventional extraction columns have been built. The Podbielniak centrifugal contactor utilizes a high-speed rotor containing a perforated spiral ribbon for mixing and separating the two liquids, while the Scheibel column consists of alternate mixing and coalescing zones in a vertical tower fitted with a central rotating shaft on which agitators are mounted in the mixing sections. The presence of moving mechanical parts in these and other powered contactors, poses repair, leakage, and servicing problems which are particularly objectionable if radioactive or highly corrosive solutions are to be processed.

R. M. Cohen is now associated with General Electric Co., ANP Project, Evendale, Ohio.

A continuous countercurrent liquid-liquid extraction column containing perforated plates was operated with a pulsed liquid phase. The effects of operating variables upon extraction efficiency and column capacity were investigated. Cyclic pulsations were imparted to the liquid in the column through a tee in the stream entering at the bottom by means of a cam-driven bellows pulsator and a diaphragm pump with checks removed. The function of the pulsations was to produce counterflow of both phases through the plate perforations and to provide a high degree of dispersion and turbulence by the continuous formation of fresh interfacial surface.

Values of H.E.T.S. as low as 9.9 in. were obtained with water as the continuous phase, and capacities as high as 660 gal./sq.ft./hr. were achieved. In general, pulse column operation was found to be most efficient at high flow rates and moderate to high pulse frequencies.



G. H. Beyer

G. H. Beyer is an associate professor of chemical engineering at Iowa State College and an associate engineer with the Institute for Atomic Research, operated by Iowa State College under contract with the Atomic Energy Commission. After obtaining a B.S. degree from the University of Wisconsin in 1944, he received a commission in the Naval Reserve and was sent to Oak Ridge, Tenn., to work on the electromagnetic separation of uranium isotopes. Four years later Dr. Beyer received his Ph.D. from the University of Wisconsin; since then he has been at Iowa State.



R. M. Cohen

R. M. Cohen received his B.Ch.E. from Clarkson Tech. in 1951 and his M.S.Ch.E. from Iowa State College in 1952. While at Iowa State on a research assistantship, he worked at the Ames Laboratory of the A.E.C. in the field of liquid extraction. He is now working at the General Electric Co. Aircraft Nuclear Propulsion Project.

In a patent by Van Dijk (13), a perforated-plate column is described in which the entire plate assembly is vibrated vertically to increase agitation between the two immiscible liquids. The same patent describes the use of fixed plates and a pulsed liquid phase. This latter modification has been designated a "pulse column" (2). Several atomic-

energy installations have built and operated such perforated-plate pulse columns, but the details have not been published (2-4, 6, 8, 10, 11). Feick and Anderson (5) studied the performance of a packed extraction column in which reciprocal motion was imparted to both liquids by means of an eccentric-driven diaphragm at the base of the column.

Similar work with a packed pulse column has been performed by Von Berg and Wiegandt (14) at Cornell University. Their results indicate that the column height required to effect a given extraction is reduced by a factor of five, in some instances, under pulsating conditions. No performance data for perforated-plate pulse columns were found in the unclassified literature.

The plate perforations in a pulse column are small enough so that counterflow of the two phases will not occur from density difference alone, but an additional force must be applied to overcome the resistance to flow. A cyclic pulse, usually imparted to the light-liquid stream entering the bottom of the column, produces alternate surges of liquid in both directions. Thus countercurrent flow occurs because of density difference in the region between successive plates and because of mechanical pulsing through the plate perforations.

Between pulsations at low pulse frequencies the two phases separate into two distinct layers in each section between adjacent plates. On the upsurge of the pulse cycle the lighter phase beneath each plate is dispersed into the heavier phase above each plate. The droplets rise through this layer and coalesce beneath the plate above. On the downsurge the heavy phase is dispersed downwards through the lighter layer in a similar fashion. Neither phase may be considered truly continuous in the column as both move countercurrently from plate to plate by alternate dispersion and recombination. Since fresh surface is created with each pulse, mass-transfer rates can be greater than for a similar packed or spray column.

At higher pulse frequencies recombination between pulses is incomplete, and the distinction between continuous and discontinuous phases becomes more apparent. The degree of dispersion and turbulence are both increased, resulting in higher extraction efficiencies. Greater throughputs are also obtainable with the increased pulsing capacity that accompanies the use of higher frequencies. By proper combinations of pulse displacement and frequency, a great variation in flow behavior may be achieved. Changes in these variables may be likened to changes in the packing characteristics for packed columns.

Because of encouraging results with pulse columns in the atomic-energy program, an unclassified investigation on a laboratory-scale column was undertaken. The major purpose of this investigation was to study the operation and performance of a pulse column as a function of flow rates, pulse amplitude and frequency, capacity, and column holdup with a convenient test system: water-boric acid-isoamyl alcohol. Variables

such as hole size and plate spacing were not studied.

Investigation

DESCRIPTION OF APPARATUS

A 20-in. section of 1-in. Pyrex pipe with two 4-in. flanged end sections, of 1½-in. diam. was assembled and fitted with Saran end plates containing standard ¼-in. Saran threaded fittings. A central ½-in. Luciflex rod, supporting ten Luciflex plates separated at 2-in. intervals by means of 5-mm. glass tubing, was inserted in the 20-in. section of the column. The 1-in. diam. Luciflex discs were punched from 1-mm. sheet and drilled with fifty-three 0.040-in. perforations/plate. This corresponded to approximately 9% free area. All gaskets were of Teflon or polythene, and all tubing was either glass, Tygon, Saran or fluorothene. All metal parts including valves were of stainless steel.

The pulse column and auxiliary equipment are shown in Figure 1. A nitrogen cylinder (A) was used to pressurize a 10-gal. glass-lined steel tank (B) containing isoamyl alcohol-boric acid feed solution. The alcohol feed was metered by means of a rotameter and needle valve (C) before entering a diaphragm pump pulsator (D). By maintaining a pressure of 10 lb./sq.in. gauge on the feed tank, pulsation of the rotameter float was kept to a minimum. Since the top of the column was open to the atmosphere, only the liquid in the column and in the section between the diaphragm pump (D) and the feed

entrance (E) was pulsed. A perforated inlet tube at the feed entrance served to disperse the pulsed liquid. The alcohol raffinate stream left the settling section at the top of the column through an overflow tube (F). The heavy liquid, distilled water, was metered through a needle valve and rotameter (G) from an overhead 15-gal. carboy. Since this line was not pulsed, pressurizing was unnecessary, and flow was maintained by a hydrostatic head of about 10 ft. The water then entered the top of the column (H), and the aqueous extract stream was taken off through a flexible leg (J) consisting of a section of Tygon tubing leading from the bottom of the column to a "Y" connection which was open to the atmosphere and another length of Tygon tubing from the open "Y" down to the receiving vessel. The position of the interface was controlled by varying the height of the flexible leg, which changed the ratio of the phase volumes in the column.

For the majority of the runs a diaphragm proportioning pump was used as the pulsator. The inlet and outlet checks were removed from one of the Saran reagent heads of a Proportioners duplex heavy duty Chem-O-Feeder in order to produce alternate surges of liquid in both directions. Pulse amplitudes were varied between 0.10 and 0.60 in. by turning a stroke-length adjusting knob. A 3-step cone pulley and belt, connected to a ¼-hp. induction motor, gave pulse frequencies of 17, 35.5 and 72 cycles/min.

Another pulsator unit was built in order to provide a greater range in pulse amplitude and

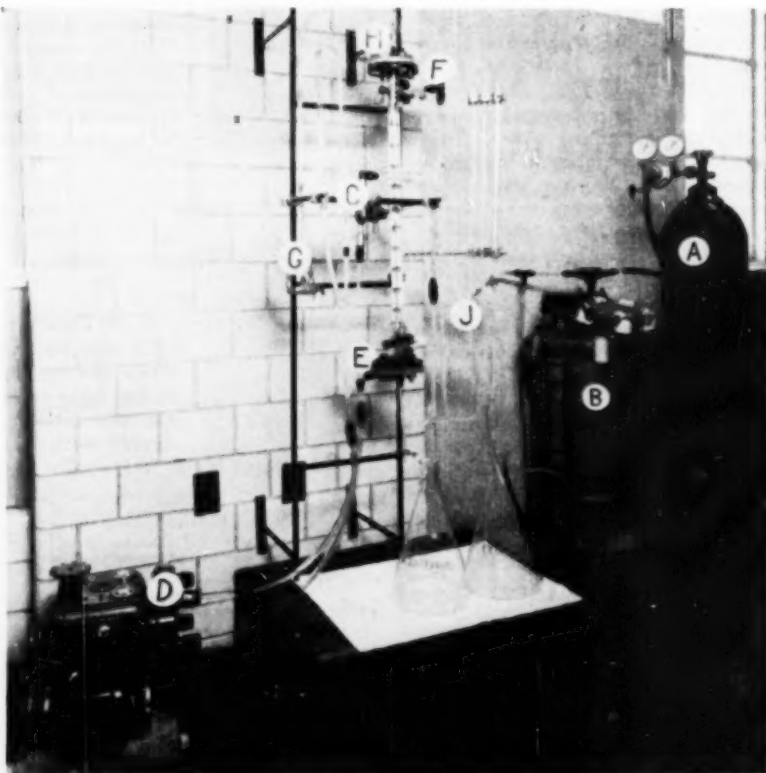


Fig. 1. Photograph of pulse column and auxiliary equipment.

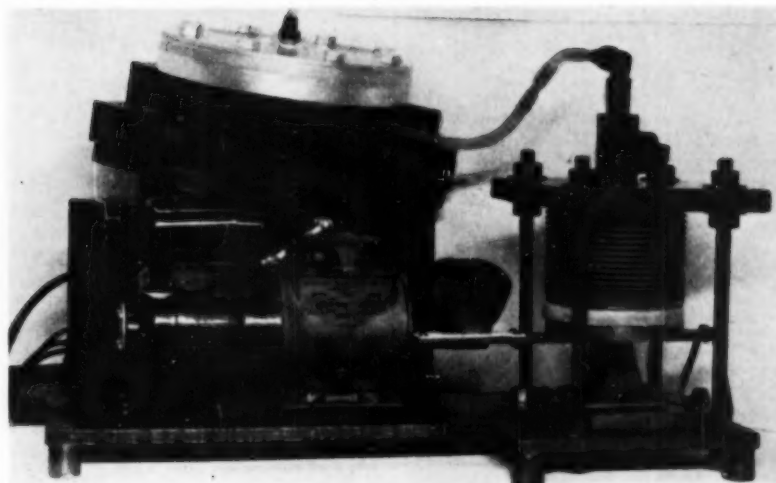


Fig. 2. Cam-driven bellows pulsator.

a continuously variable frequency control. This mechanism, shown in Figure 2, consisted of a 4.7-in. diam. Fulton-Sylphon brass bellows actuated by a motor-driven cam via a lever. Pulse amplitudes were varied between 0.10 and 2.00 in. by means of a screw control which determined the position of the fulcrum under the lever. A Graham variable-speed transmission was used to select the desired frequency. In order to prevent contact of the column liquids with the brass bellows, a diaphragm assembly containing a 7-in.-diam. polythene-lined, neoprene diaphragm was inserted in the line between the bellows and the column. The bellows side of the assembly was water filled so as to transmit the pulse, hydraulically, to the diaphragm without dampening. This unit was satisfactory at low pulse frequencies (17 cycles/min.), but at higher frequencies the output torque of the variable-speed transmission was not great enough to overcome the inertia of the bellows. Consequently, the diaphragm proportioning pump was used in the runs at 35.5 and 72 cycles/min.

OPERATING PROCEDURE

The feed tank was filled with isoamyl alcohol-boric acid solution made up to a concentration of approximately 0.008 g./ml. of boric acid. The distilled water valve was opened and the pulsator was started in order to fill the column with the continuous phase. When the liquid level in the column was near the top of the 1-in.-diam. section, the liquid flow was shut off and the pulse amplitude was adjusted by measuring the total linear displacement of the upper interface. Pulse amplitudes were checked similarly at the completion of each run. The feed tank was then pressurized to 10 lb./sq.in. gauge with nitrogen, and both flow rates were regulated by stainless steel needle valves. Calibrated ratameters were used for metering both liquids, while the flow rates were more accurately adjusted during the early part of each run by timing measured volumes of the

effluent streams. Since the distilled water solvent was previously saturated with pure isoamyl alcohol and the alcohol feed was saturated with water, no significant volume changes took place during extraction. The interface was maintained at a constant level by adjusting the height of the flexible aqueous take-off leg. Steady-state operation was achieved after 4 to 5 changeovers of the continuous phase. Samples were collected from both effluent streams 3 hr. after start-up to insure the attainment of equilibrium conditions. Analysis for boric acid was by the procedure recommended by Kalthoff and Sandell (7). For the low-flow fluid (water), a 3-hr. run permitted 5 to 6 changeovers at 10 cc./min., and 12 to 14 changeovers at 25 cc./min. Both flows were then shut off and the pulsator disconnected while the column was drained into a graduated cylinder in order to measure the ratio of phase volumes in the column. The liquid in the end sections was included in the holdup inventory, and as such the values obtained were not true holdup ratios. However, since the phase volumes in the end sections remained constant throughout the runs, the measured volume ratios served to indicate the trends in this variable with changes in the other parameters.

CALCULATION OF EFFICIENCY OF TRANSFER

Performance data for design purposes may be expressed in terms of H.E.T.S. (height equivalent to a theoretical stage) or H.T.U. (height of a transfer unit). While H.E.T.S. varies considerably with the properties of the system in an unpredictable manner, H.T.U. data are correlated somewhat better since this method is inherently more consistent with the actual extraction picture. However, the practicability of H.T.U. correlational procedures is limited because of the lack of experimental data on individual film transfer coefficients and film H.T.U.'s. Thus, although the

H.E.T.S. concept is fundamentally unsound when applied to operations where the concentration changes differentially with height, it is often used for designing continuous extraction equipment since H.E.T.S. values are more easily computed than H.T.U.'s.

In this investigation values of H.E.T.S. were used to express extraction efficiencies. Over-all H.T.U.'s were also calculated for comparative purposes. Since the equilibrium line was shown to be straight (1), and the operating line could be assumed straight when using alcohol saturated with alcohol, an analytical solution of the McCabe-Thiele method was used to give more accurate results than the usual graphical procedure (1, 9, 12). The following equations were used for the special case of solute-free solvent with the operating line above the equilibrium line (extraction from alcohol into water):

$$n = \frac{\log \left[1 - \left(\frac{y_2}{y_1} - 1 \right) \left(\frac{m}{a} - 1 \right) \right]}{\log \left(\frac{a}{m} \right)} \quad (1) \text{ where } a \neq m$$

$$n = \frac{y_2}{y_1} - 1 \quad (2) \text{ where } a = m$$

In the above equations,

- n = number of theoretical stages
- a = slope of operating line determined by analysis
- m = slope of equilibrium line = 0.2909
- y = concentration of boric acid in alcohol phase
- 1 and 2, subscripts, refer to the lower and higher concentrations, respectively.

H.E.T.S. values were calculated by dividing the number of theoretical stages thus obtained into the column height. Over-all H.T.U.'s were computed directly from values of H.E.T.S. by the following relations, which are valid only for straight operating and equilibrium lines:

$$(H.T.U.)_{OG} = \frac{\left(\frac{m}{a} - 1 \right) (H.E.T.S.)}{\ln \left(\frac{m}{a} \right)} \quad (3) \text{ where } a \neq m$$

$$(H.T.U.)_{OL} = \left(\frac{a}{m} \right) (H.T.U.)_{OG} \quad (4) \text{ where } a \neq m$$

$$(H.T.U.)_{OG} = (H.T.U.)_{OL} = H.E.T.S. \quad (5) \text{ where } a = m$$

In the above equations the subscripts OG and OL refer to over-all values based on the dispersed and continuous phases, respectively.

Table 1.—Effect of Flow Rates on Extraction and Holdup at a Low Pulse Frequency

PULSE FREQUENCY = 17 cycles/min.
PULSE AMPLITUDE = 0.35 in.
CONTINUOUS PHASE: Water

Run No.	Water rate, L (cc./min.)	Alcohol rate, G (cc./min.)	Holdup ratio	H.E.T.S. (in.)	(H.T.U.) _{oa} (in.)	(H.T.U.) _{ol} (in.)	Material balance (% error)
19	10	10	0.130	21.2	12.2	41.8	+0.06
16	10	15	0.120	21.6	14.9	33.1	+2.04
5	10	25	0.158	20.8	17.8	24.5	+0.05
6	10	40	0.173	21.5	22.9	20.2	-1.29
7	10	60	0.196	19.4	24.9	15.4	-3.03
8	10	100	0.214	15.1	26.9	9.3	-0.24
20	10	120	0.283	16.2	32.6	9.2	+0.43
17	25	15	0.123	21.0	9.8	58.4	-3.72
18	25	20	0.143	25.3	13.4	56.6	+1.52
9	25	25	0.143	28.3	17.1	51.9	+8.54
10	25	50	0.212	26.7	21.4	34.0	+4.32
11	25	75	0.294	28.4	26.1	31.0	-1.57
22	50	15	0.136	154.	59.2	628.	+6.39
13	50	25	0.173	35.1	16.1	100.	+7.69
23	50	35	0.216	27.9	14.0	68.5	+0.21
21	50	42.2	0.262	32.9	17.7	72.0	+0.09

Table 2.—Effect of Flow Rates on Extraction and Holdup at a High Pulse Frequency

PULSE FREQUENCY = 72 cycles/min.
PULSE AMPLITUDE = 0.20 in.
CONTINUOUS PHASE: Water

Run No.	Water rate, L (cc./min.)	Alcohol rate, G (cc./min.)	Holdup ratio	H.E.T.S. (in.)	(H.T.U.) _{oa} (in.)	(H.T.U.) _{ol} (in.)	Material balance (% error)
36	10	25	0.194	13.0	11.7	14.5	+7.20
25	10	50	0.219	13.8	17.5	11.1	+3.63
39	10	75	0.318	11.8	18.6	7.9	+2.61
38	10	100	0.311	10.5	19.4	6.3	+1.58
41	10	150	0.338	11.1	26.1	5.7	+0.97
33	25	25	0.228	13.1	7.8	24.9	+6.58
34	25	50	0.263	14.1	11.3	17.9	+6.26
35	25	75	0.297	13.5	13.1	14.0	+4.46
37	25	100	0.234	14.0	15.7	12.6	+3.99
40	25	150	0.340	12.1	17.0	8.9	+3.70

Table 3.—Effect of Pulse Amplitude and Frequency on Extraction and Holdup at Constant Flow Rates

ALCOHOL FLOW RATE = 50 cc./min.
WATER FLOW RATE = 10 cc./min.
CONTINUOUS PHASE: Water

Run No.	Pulse frequency (cycles/min.)	Pulse amplitude (in.)	Holdup ratio	H.E.T.S. (in.)	(H.T.U.) _{oa} (in.)	(H.T.U.) _{ol} (in.)	Material balance (% error)
24	72	0.15	0.165	18.4	22.8	15.0	+1.82
25	72	0.20	0.219	13.8	17.4	11.1	+3.63
29	72	0.30	0.381	12.0	14.7	9.9	+0.75
31	72	0.40	0.450	11.5	13.6	9.8	-2.25
27	35.5	0.15	0.152	22.2	27.2	18.3	+0.77
26	35.5	0.20	0.151	17.7	21.6	14.7	+0.39
28	35.5	0.35	0.222	15.1	18.8	12.3	+2.38
30	35.5	0.45	0.298	12.3	14.9	10.3	-0.26

Table 4.—Effect of Continuous Phase on Extraction

ALCOHOL FLOW RATE = 75 cc./min.
WATER FLOW RATE = 25 cc./min.

Run No.	Pulse frequency (cycles/min.)	Pulse amplitude (in.)	Continuous phase	H.E.T.S. (in.)	Material balance (% error)
35	72	0.20	Water	13.5	+4.46
42-8	72	0.20	Alcohol	29.0	+0.88
45	35.5	0.45	Water	9.9	+1.31
43-8	35.5	0.45	Alcohol	24.7	+1.79

PERFORMANCE DATA

Experimental runs were planned in such a way that the effect of each variable on column performance was investigated separately in a series of runs in which the other variables were held constant. In order to cover a range of column operation adequately, the method of attack was to study each variable between its minimum and maximum values for representative low, moderate and high values of the other parameters. Several preliminary runs were made to study flooding behavior under various flow and pulse conditions so that operating limits might be approximated beforehand and extraction runs planned accordingly.

Effect of flow rates. Three series of extraction runs were made in which alcohol (dispersed) flow rates were varied over the entire permissible operating range at constant pulse conditions of 17 cycles/min. and 0.35-in. amplitude. Although the alcohol phase recombined between pulsations into a layer $\frac{1}{4}$ - $\frac{1}{2}$ in. thick beneath each plate, as shown in Figure 3, it was for the most part in a state of dispersion. The three sets of runs were made at constant aqueous-phase flow rates of 10, 25, and 50 cc./min., respectively, and the maximum alcohol flow rate in each series was just below that producing incipient flooding in the aqueous effluent stream. Extraction as well as holdup data for these runs are presented in Table 1 where holdup ratios are defined as: volume of discontinuous phase per volume of continuous phase in the column. Results of two similar series of runs made at 72 cycles/min. and 0.20-in. amplitude, for constant continuous-phase flow rates of 10 and 25 cc./min., are presented in Table 2.

Figures 4 and 5 show the effect of dispersed phase flow rate on H.E.T.S. at both high and low pulse frequencies for continuous phase flow rates of 10 and 25 cc./min., respectively. These data were also correlated in terms of over-all H.T.U.'s, which were plotted in Figure 6 as (H.T.U.)_{oa} vs. the ratio of the slope of the equilibrium line to that of the operating line, on logarithmic coordinates. The slope of the operating line was determined by analysis. Since the slope of the equilibrium line is constant ($m = 0.2909$), Figure 6 essentially indicates the dependence of (H.T.U.)_{oa} upon the flow ratio G/L raised to some power. Pulse conditions, as a parameter in such a plot, are entirely analogous to the "packing characteristics" parameter frequently used in similar correlations of packed column performance data. It is to be noted in Figure 6 that, whereas the data at the high pulse frequency appear to be a unique exponential function of G/L regardless of individual flow rates, the data at the lower pulse frequency seem to group into separate lines, each representing a constant continuous phase flow rate. At 72 cycles/min. and 0.20-in. amplitude, the data are best expressed by the equation:

$$(H.T.U.)_{oa} = 8.32(G/L)^{0.20} \text{ in.} \quad (6)$$

Figure 7 shows the effect of flow rates on

volumetric holdup ratio. An increase in either flow rate increases the dispersed phase holdup, and flooding is approached rapidly with an increase in dispersed phase flow rate at high continuous phase flow rates. Thus for $L = 50$ cc./min. flooding occurred at $G = 45$ cc./min., while for $L = 10$ cc./min. values of G as high as 125 cc./min. were obtained at incipient flooding. For the low pulse frequency used (17 cycles/min.) incipient flooding took place at a holdup ratio of approximately 0.30, regardless of flow rates or ratios. At higher frequencies, clear-stream operation was observed with holdup ratios as high as 0.50, allowing greater throughput.

Effect of pulse amplitude and frequency.

A series of runs was made at constant continuous and discontinuous flow rates of 10 and 50 cc./min., respectively, to determine the effect of pulse amplitude on H.E.T.S. and holdup ratios at frequencies of 35.5 and 72 cycles/min. These data are tabulated in Table 3 and plotted in Figures 8 and 9. It is seen that extraction efficiency is greatly improved by an increase in either pulse amplitude or frequency. At 72 cycles/min., values of H.E.T.S. dropped rapidly with an increase in pulse amplitude between 0.15 and 0.30 in., but any further increase had relatively little effect on H.E.T.S. Clear-stream operation at amplitudes greater than 0.40 in. was impossible because of excessive emulsification of the two phases. At 35.5 cycles/min. the operating range was greater, and H.E.T.S. values decreased uniformly with increasing amplitudes at a more gradual rate than at 72 cycles/min.

At moderate and high frequencies holdup ratios were found to increase with pulse amplitudes. This increase was more rapid at 72 cycles/min. than at 35.5 cycles/min., as can be seen in Figure 11. At small pulse amplitudes (0.10 to 0.20 in.) and a frequency of 72 cycles/min., the dispersed phase was broken up into

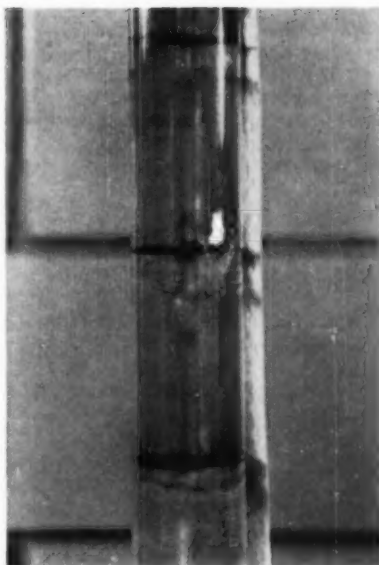


Fig. 3. Close-up of column, showing separation of phases.

a fine emulsion in the lower section of the column, resulting in excessive light-liquid carryover in the heavy-liquid effluent stream. When operating at high pulse amplitudes and the same frequency, the column appeared to be filled with a coarse emulsion, and flooding occurred in both effluent streams. Thus, the clear-stream operating range at 72 cycles/min. was from 0.20 to 0.40 in., while at lower frequencies the range was greater.

Because of the manner in which extraction was dependent on both frequency and amplitude, it was decided that neither of the two should be considered independently, but rather that both should be grouped into one variable.

Thus it was considered instructive to plot H.E.T.S. data for conditions of constant flow rates as a function of the product (amplitude) \times (frequency), since this quantity, multiplied by column area, represents the pulsed volume. Figure 10 is such a plot, representing the previous data of Table 3 supplemented with additional runs at 17 cycles/min. The points fall along a single curve with little scattering.

Effect of continuous phase. The continuous phase in the pulse column was determined by the interface location, which was governed by the height of the aqueous take off leg. With water as the continuous phase the interface was located at the top of the column, whereas a bottom interface was obtained with the alcohol phase continuous. Table 4 presents the results of two pairs of runs made under identical conditions, operating with top and bottom interfaces, respectively. This comparison shows that transfer is more efficient in the pulse column for the system water-boric acid-isomyl alcohol, when the water phase is continuous.

Comment

In Figures 4 and 5 values of H.E.T.S. are seen to be fairly insensitive to changes in flow rates at the higher pulse frequency. At the lower frequency, values of H.E.T.S. vary over a somewhat wider range.

The extraction picture at the lower frequency is complicated by the fact that each phase is alternately dispersed and continuous. The thickness of the coalesced phase under each plate becomes an important factor, in addition to the droplet size and the degree of turbulence. The length of time during which a unit volume of one phase is in dispersed contact with the other phase is less in a pulse column than in a spray

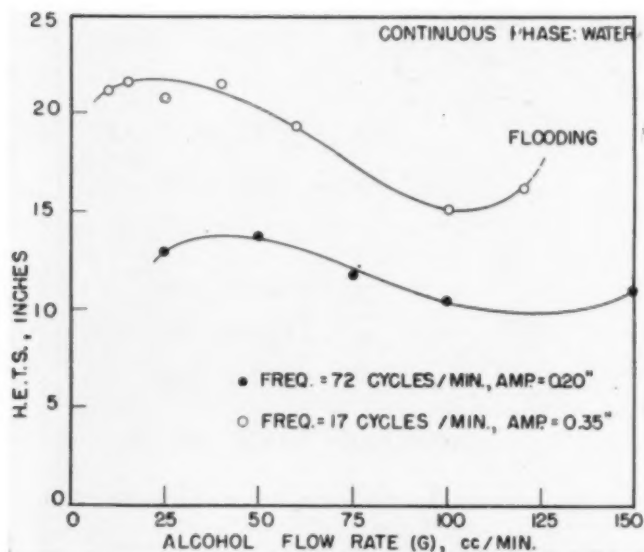


Fig. 4. Effect of dispersed phase flow rate on H.E.T.S. at continuous phase flow rate of 10 cc./min.

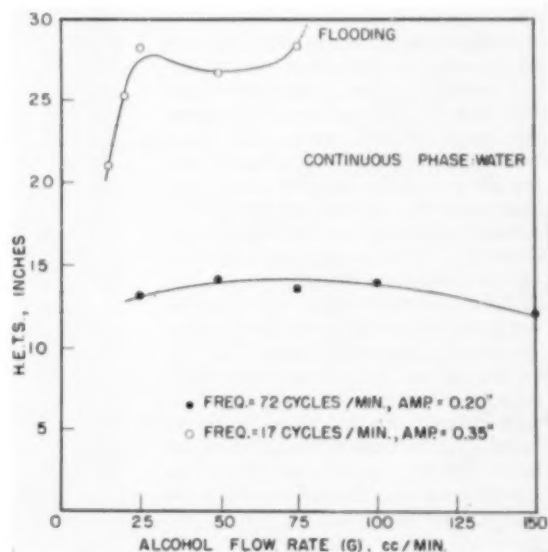


Fig. 5. Effect of dispersed phase flow rate on H.E.T.S. at continuous phase flow rate of 25 cc./min.

column of the same dimensions operating under similar conditions. The pulse column contact time (during which extraction occurs) is equal to spray column contact time multiplied by the fraction of the pulse cycle during which the phases are actually dispersed. The periods of re-coalescence, when quiescent conditions prevail, contribute little to mass transfer. Thus the greater efficiency of a pulse column, compared to a spray column, must be attributed to the repeated formation of fresh surface and the high degree of turbulence, rather than to increased contact time.

Flooding of a pulse column can be caused by inadequate pulsing capacity to handle the flow of dispersed phase at low pulse frequencies and amplitudes, and by emulsification because of inadequate settling at high pulse frequencies and amplitudes. It is interesting to try to predict the alcohol flow rate at which flooding should occur because of inadequate pulsing capacity for the data shown in Figure 5 at 17 cycles/min., amplitude 0.35 in. Since the column cross section was about 5 sq.cm., the pulsed volume can be calculated as $0.35(2.54)(5)(17) = 75$ cc./min. The same pulsing conditions at the lower water rate of Figure 4 handled 125 cc./min. of alcohol before flooding, indicating that factors other than pulsed volume must be considered. In general, the region of low frequency and amplitude, where danger of this type of flooding exists, is primarily of academic interest. Markedly better throughput and efficiency are possible with more vigorous pulsing, which entirely eliminates the separation of phases shown in Figure 3.

With vigorous pulsing a great deal of back mixing occurs within the column. This can be shown by an analysis of Run 45, where the alcohol flow rate was 75 cc./min., the water flow rate 25 cc./min., and the pulsed volume $0.45(2.54)(5)(35.5) = 200$ cc./min. Throughout the course of each minute, 200 cc. of liquid are drawn into the pulsator during the downsurge and 200 cc. are discharged by the pulsator on the upsurge. Alcohol and water enter the column continuously, but leave only on the upsurge. On the downsurge the pulsator receives $75/2$ or approximately 38 cc. of entering alcohol, plus 162 cc. of liquid sucked downward through the plates. This 162 cc. is made up of 25 cc. of water which must pass downward through the plates each minute, plus 137 cc. of liquid recycle. On the upsurge the pulsator delivers 200 cc., while some 37 cc. of alcohol continues to enter through the alcohol inlet line. This 237 cc. is disposed of as follows: 25 cc. of water must flow out the water exit line, leaving 212 cc. of liquid to be forced upward

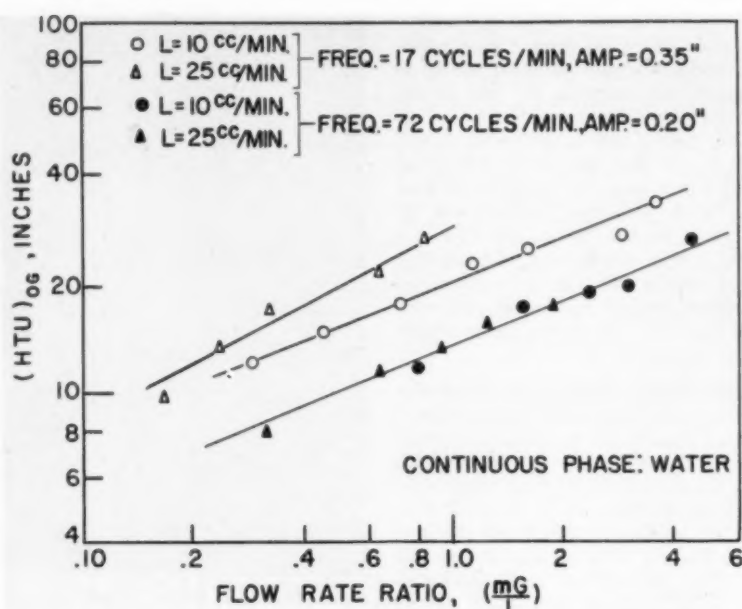


Fig. 6. Effect of flow rate ratio on over-all height of a transfer unit.

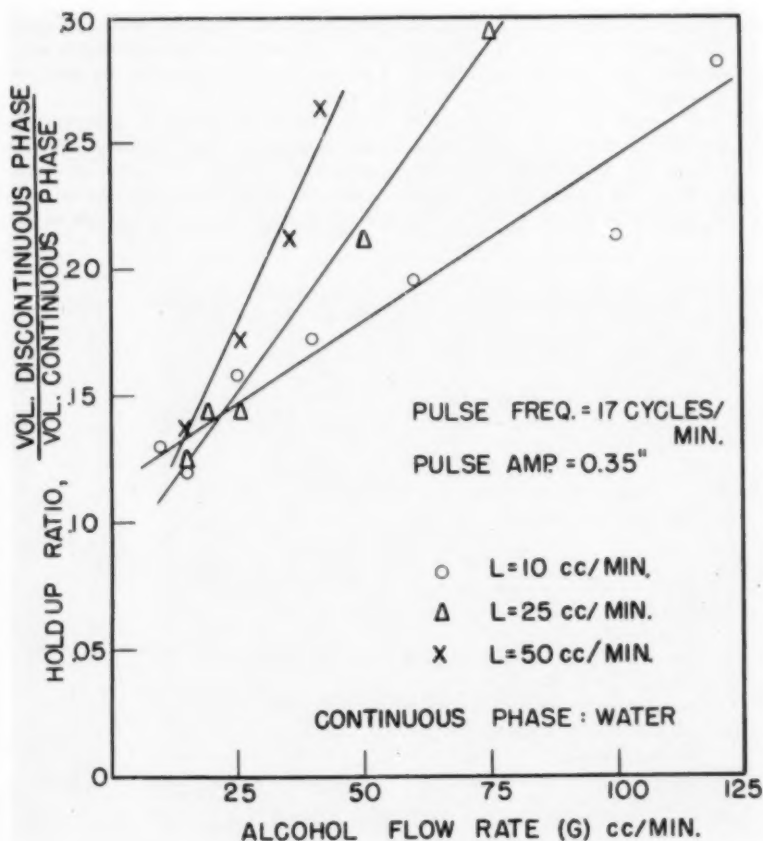


Fig. 7. Variation of holdup ratio with flow rate.

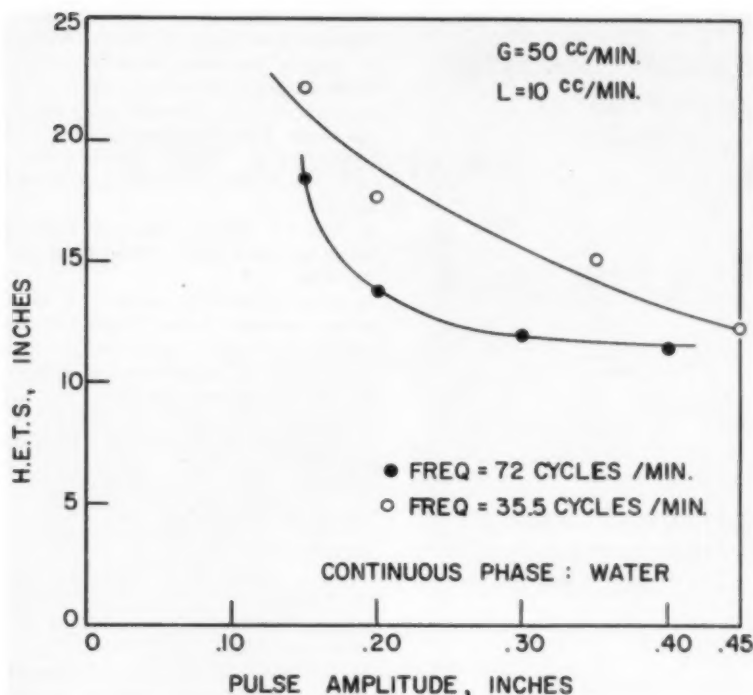


Fig. 8. Effect of pulse amplitude on H.E.T.S. at moderate and high pulse frequencies.

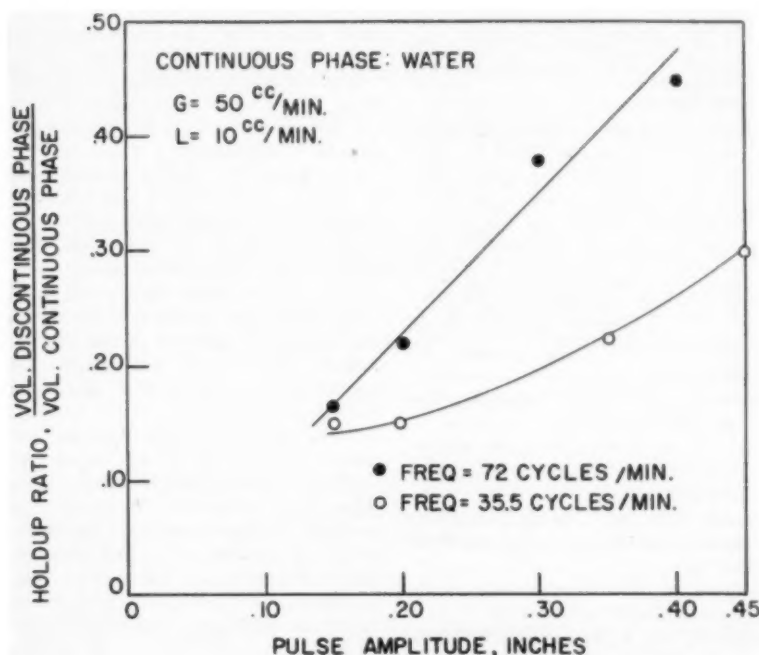


Fig. 9. Effect of pulse amplitude on holdup ratio at moderate and high pulse frequencies.

through the plates; 75 cc. of alcohol must pass upward through the plates each minute, so $212 - 75 = 137$ cc. of liquid are also recycled on the upsurge. Depending on the choice of pulsing conditions, the amount of recycle is adjustable within fairly wide limits. In effect, a vigorously pulsed column operates as a baffled mixer with countercurrent flow superimposed on this cocurrent mixing.

As Figure 10 shows, increasing amplitude or frequency increases efficiency up to a certain point, beyond which more vigorous pulsing is of little benefit. It seems likely that this curve represents the sum of two opposing effects. As the pulse frequency is increased, dispersion and turbulence increase and better contacting efficiency results. However, an increase in the amount of back mixing takes place simultaneously, detracting from the beneficial effects of dispersion and turbulence, and the sum total of both these effects is pictured in Figure 10. The limiting values of pulse amplitude and frequency are dependent to a large degree on the physical characteristics of the liquids contacted. If the interfacial tension of the two phases is low, as is often the case with liquids of high mutual solubility, there may exist a definite tendency toward the formation of stable emulsions. Also, cavitation may occur in the line from the column to the pulse generator due to the development of localized pressures lower than the vapor pressure of the pulsed fluid. The choice of pulse amplitude and frequency must take into account the possibility of cavitation and emulsion formation.

The location of the interface determines which of the two phases in the column is the continuous one under conditions of vigorous pulsing. In general, the physical properties of the system which affect the film thickness, the degree of dispersion and the droplet velocity, as well as the chemical properties which affect the plate-wetting characteristics, determine the choice of interface location. The phase which preferentially wets the plates is sometimes chosen as the continuous phase, since finer dispersion of the discontinuous phase is then obtainable. However, if the interfacial tension is low, dispersion of either phase will usually be adequate, and viscosity will often be the determining factor in choosing the continuous phase. Such was the case with the system: water-boric acid-isoamyl alcohol, where higher rates of extraction were observed with the water phase continuous. The viscosity of the alcohol was 4.5 cp., as compared to 1.0 cp. for water at 20° C., so it might be expected that the principal resistance to diffusion lies in the alcohol phase. The greater viscosity of the alcohol phase resulted in slower settling rates for the dispersed water droplets

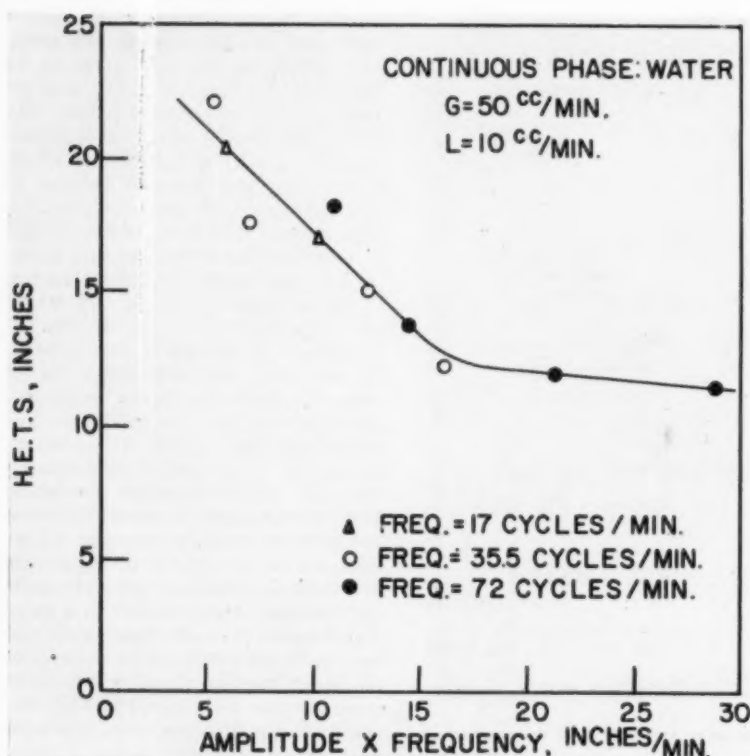


Fig. 10. H.E.T.S. as a function of the product (amplitude) \times (frequency) at constant flow rates.

than when the alcohol phase was continuous. Also contributing to lowered efficiency is the fact that dispersing the low-flow fluid makes less interfacial area available, per pulse, than dispersing the high-flow fluid.

Because of its higher efficiency and lower column height (approximately $\frac{1}{3}$ to $\frac{1}{2}$ that of a similar packed column performing the same separation), the pulse column should be considered where low head room or shielding requirements for radioactive solutions are important considerations. High throughput capacities may allow the use of columns of smaller diameter. Construction is relatively simple and the absence of moving mechanical parts within the column keeps leakage and maintenance low. The pulse column is a versatile extractor with good efficiency over a wide range of flow conditions. The convenience of changing packing characteristics external to the column by adjusting pulse amplitude and frequency is often of value in experimental work.

Of course, these advantages point up certain disadvantages. Pulsing liquids costs money and the higher initial cost must be weighed against savings from increased throughput and lowered height requirements. For large volumes, pulsing at constant and rapid rates poses mechanical problems. Highly viscous liquids and volatile liquids require special evaluation. Then too, small holes

have a tendency to clog even with nominally clear streams.

One of the chief barriers, however, to the proper utilization of new devices for solvent extraction is lack of information on design and performance. It is hoped that this paper will stimulate further experimentation and publication on the subject of pulse columns and their place in the field of extraction equipment.

Acknowledgment

The authors wish to express their sincere appreciation to the Ames Laboratory of the Atomic Energy Commission and the Institute for Atomic Research of Iowa State College for the use of their facilities and equipment. The assistance of N. Barson, who offered helpful suggestions regarding the analytical and calculating procedures, is gratefully acknowledged.

Literature Cited

1. Barson, N., and G. H. Beyer, *Chem. Eng. Progress*, **49**, 243 (1953).
2. Burns, W. A., C. Groot, and C. M. Slansky, U. S. Atomic Energy Commission Report. Report HW-14728 (1949).
3. Cooper, V. R., and C. Groot, U. S. Atomic Energy Commission Report. Report HW-20305 (1952).
4. Ellison, C. V., U. S. Atomic Energy Commission Report. Report ORNL-912 (1951).
5. Feick, G., and H. M. Anderson, *Ind. Eng. Chem.*, **44**, 404 (1952).
6. Jealous, A. C., U. S. Atomic Energy Commission Report. Report ORNL 51-B-162 (1951).

7. Kolthoff, I. M., and E. B. Sandell, "Textbook of Inorganic Quantitative Analysis," rev. ed., The Macmillan Co., New York (1948).

8. Lehman, H. R., U. S. Atomic Energy Commission Report. Report UCRL-1558 (1951).

9. Perry, J. H., "Chemical Engineers' Handbook," 3rd ed. McGraw-Hill Book Co., Inc., New York (1950).

10. Pike, F. P., and J. I. Stevens, U. S. Atomic Energy Commission Report. Report ORNL 50-7-40 (1950).

11. Rubin, B., and H. R. Lehman, U. S. Atomic Energy Commission Report. Report UCRL-718 (1950).

12. Treybal, R. E., "Liquid Extraction," McGraw-Hill Book Co., Inc., New York (1951).

13. Van Dijk, W. J. D., U. S. Patent 2,011,186 (Aug. 13, 1935). Abstracted in *Chem. Abst.*, **29**, 6476 (1935).

14. Von Berg, R. L., and H. F. Wiegand, *Chem. Eng.*, **59**, 189 (June, 1952).

Discussion

Aylmer H. Maude (Hooker Electrochemical Co., Niagara Falls, N. Y.): Does the plate spacing affect the height equivalent to a theoretical stage?

R. M. Cohen: In the pulse column, as in sieve-plate columns, a reduction in plate spacing lowers the height equivalent to a theoretical stage. Although a 2-in. spacing was used in all the runs, a considerable improvement in extraction might be expected if a 1-in. spacing were to be used instead. In effect, this would correspond to an increase in the amount of column packing. This would tend to lower the throughput somewhat, and too small a plate spacing would result in flooding or emulsification. The optimum plate spacing with respect to both extraction efficiency and throughput would depend to a large degree on the frequency and amplitude of pulsation.

A. N. Hixson (University of Pennsylvania, Philadelphia, Pa.): Does it make any difference from which phase the extraction is being made?

R. M. Cohen: It is usually desirable, from the standpoint of efficiency, for extraction to take place from the phase in which the solute is less soluble; in other words, from the phase having the higher diffusional resistance. For the system used in this study, where boric acid distribution favors the water phase, the direction of transfer was from the alcohol to the water phase. The number of theoretical stages is greater for transfer in this direction.

It was also found that extraction was greatly improved with the water phase continuous (extraction from the discontinuous phase) rather than with the alcohol phase continuous (extraction from the continuous phase). In practice, solvent recoverability, relative flow rates, and plate-wetting characteristics would determine the choice of continuous phase and direction of solute transfer.

Presented at A.I.Ch.E. Biloxi meeting

The Design of Nuclear Power Plants



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The development of nuclear power for industrial use is one of the most intriguing prospects of our present era. The focal point of this development is the nuclear energy pile or reactor which is essentially a device for converting the potential energy of uranium or thorium into useful heat.

In the decade that has passed since scientists first achieved a self-sustaining nuclear reaction, continuous progress in the development of reactors for utilizing this reaction has taken place. At the present time more than twenty nuclear reactors are in operation or under construction in the United States. These are located as follows:

- a. Hanford, Wash.: Three war-built plutonium production reactors plus postwar production reactors.
- b. Savannah River, S. C.: Production reactors
- c. Arco, Idaho: Two sizeable new research reactors and a land-based prototype of a submarine reactor.
- d. Argonne National Laboratory, Ill.: Three small research reactors.
- e. Schenectady, N. Y.: Land-based prototype for an improved submarine reactor.
- f. Los Alamos, N. M.: Two small research reactors.
- g. Oak Ridge, Tenn.: One war-built pilot model reactor plus three small reactor experiments.
- h. Brookhaven, N. Y.: One research reactor.
- i. North Carolina State University: One small research reactor.

Although none of the reactors listed make practical use of nuclear power, achievements in this direction in the

mobile reactor program are significant. In June, 1952, the President laid the keel for the first atomic powered submarine and this vessel will be afloat by 1954. Atomic power for large ships is being developed and by 1963 nuclear propulsion for airplanes may be realized. In other words, the technical problems of nuclear power production are being solved today. The use of nuclear energy for industrial power, however, is less certain since this involves economic as well as technical questions.

To achieve a nuclear power system which is economic as well as technically feasible requires the type of developmental approach with which the scientist is familiar. The actual design of the reactor system, moreover, requires an engineering approach, but since this involves new concepts, it is not well understood. This paper attempts to present an engineering approach to the design of nuclear reactors that might be used for power plants, and to show analogies between this and conventional design methods.

Basic Information

Reactions between neutrons and the nuclei of atoms can occur in a variety of ways. In the most common of these nuclear reactions, the nucleus "captures" the neutron, forming an isotope of higher atomic weight. This isotope is usually radioactive, decaying to form a new element. In the "fission" reaction, the nucleus splits into two parts, forming a variety of lighter elements

and releasing a number of additional neutrons. Although many heavy nuclei undergo both fission and capture reactions with neutrons, only a few have a higher probability for fission than capture. Since these few generate excess neutrons and are capable of sustaining a nuclear chain reaction they are called fissionable nuclei. The most common fissionable nucleus is the uranium isotope U^{235} which occurs as 0.71% of the uranium found in nature. The remaining 99.3% is uranium-238 which has a low fission to capture probability, and does not fission enough to sustain a nuclear chain reaction. It is possible to convert U^{238} and thorium-232, which is also nonfissionable, into the fissionable nuclei of plutonium-239 and U^{233} , respectively, by bombarding these materials with neutrons.

When U^{235} fissions, it releases on the average 2.5 neutrons per atom fissioned. Since only one neutron is required to cause fission, the remaining 1.5 neutrons are available for transforming some of the U^{238} present into Pu^{239} and making up losses. These losses consist of absorption by U^{235} without fission, absorption by the control rods, construction materials, and coolant, and escape from the reactor. When the production of neutrons exceeds all losses, an expanding chain reaction develops, and the rate of heat generation will increase. A constant heat production rate may be obtained by adding neutron absorbers to maintain a delicate balance between neutron production, absorption, and losses.

Although the neutron multiplication process takes place in times of the order of milliseconds, not all the neutrons are emitted instantaneously. A small fraction (< 1%) is emitted from short-lived fission products and "delayed" as much as a few minutes after the fission occurs, which effectively increases the time between successive generations. Thus, the delayed neutrons make the control of a reactor practical with mechanically driven rods containing neutron absorbers.

The large amount of energy created by the fission reaction arises from the fact that the combined masses of the fission products are about 0.1% less than the original U^{235} . This difference in mass is converted into energy which manifests itself primarily in the form of kinetic energy of the fission products. These newly formed atoms travel as far as 0.1 mm. and create heat on impact with neighboring atoms. Neutrons, on the other hand, diffuse several feet in a reactor before causing fission or being absorbed. The fission products damage fuel elements by ionization or effectively knocking atoms out of place in their lattices.

A divergent chain reaction created in

a block of fissionable material forms the basis for the atomic bomb. A system like this, however, is not practical as a source of electric power since the reaction cannot be stopped and there is no method of recovering the heat. Consequently, to achieve a practical heat generator, it is necessary to add various other components to the nuclear fuel. These are listed in Table I with typical materials used for the reactor components.

The "moderator" is a low atomic weight material placed in the reactor to slow down the neutrons from their original high velocities. Each time a neutron collides with a moderator atom, it loses a fraction of its energy, until finally it is moving at the same velocity as the moderator atoms themselves. At this velocity or energy, it is said to be thermal.

By using a moderator, one takes advantage of the fact that fissionable materials absorb slow or thermal neutrons more readily than fast neutrons. Since most of the thermal neutron absorption leads to fission, this process takes place more efficiently with slow than with fast neutrons. For this reason, a chain reaction can be sustained in natural uranium with thermal neutrons but not with fast neutrons. Reactors are designated as thermal, intermediate, or fast, depending upon whether the average energy of the neutrons causing fission is thermal, intermediate, or fast.

Although many materials of high atomic weight fission to a certain extent with fast neutrons, a fast fission chain reaction can be sustained only in nuclear fuels which contain relatively large percentages of U^{233} , U^{235} , or Pu^{239} . Thus, fast reactors normally require large inventories of these fissionable materials.

The nuclear engineer's main contribution is the selection and arrangement of the reactor components to give the most efficient and economic design. This process of selection involves many interrelated factors, so that it is not always possible to retrace the steps leading to the final design. However, the usual design procedure first involves consideration of the factors which estab-

lish the requirements of the nuclear system. This is followed by an analysis and solution to the heat removal problem. Finally, the engineer deals with the design of the remaining portions of the reactor structure and associated facilities.

Features of a nuclear plant will be discussed in a general way in Part I, Design Procedure, while the design of a specific hypothetical reactor will be traced in Part II, Designing a Typical Power Reactor.

Part I—Design Procedure

In the design procedure shown below, steps (a) through (e) establish the system requirements, steps (f) through (j) consider the heat-removal problem, and step (k) completes the design.

- a. Establish power level
- b. Select components for reactor system
- c. Establish size limitations of reactor core
- d. Estimate required power density in the core
- e. Determine amount of fissionable material required (i.e., degree of enrichment)
- f. Select coolant
- g. Select method of heat removal
- h. Determine optimum arrangement of fuel and moderator
- i. Design fuel elements
- j. Establish operating conditions
- k. Design reactor structure, shield, and associated facilities.

ESTABLISHING SYSTEM REQUIREMENTS

The factors which establish the requirements of the nuclear reactor system, items (a) through (e), are discussed below.

a. Power Level. The power level is usually established on the basis of the function of the reactor. The various purposes for which reactors have been built or are being studied, and the corresponding power levels are shown in Table 2.

Thus, the starting point in designing any reactor is the maximum power level. This power level corresponds to the full load rating of an electric motor or generator. It is the power at which the reactor is designed to operate continuously without overheating or malfunctioning. As the design progresses, this

TABLE 1.—NUCLEAR REACTOR COMPONENTS

Component	Material	Function
Nuclear fuel	U^{235} , U^{233} , Pu^{239}	Sustains fission reaction
Fuel diluent	U^{238} , Th, Al, Fe	Provides heat-transfer surface and absorbs excess neutrons to generate new nuclear fuel.
Moderator	C, H ₂ O, D ₂ O, Be	Reduces neutron energy
Coolant	Air, H ₂ O, D ₂ O, Na, Bi	Removes heat
Control elements	Cd, B, Hf	Adjusts neutron level
Structure	Al, Zr, Fe	Supports and contains fuel elements
Shield	Concrete, Fe + H ₂ O	Protects personnel from radiation

TABLE 2.—TYPES OF REACTORS AND POWER LEVELS

Type of Reactor	Power Level Range, Heat
Research	0.1 watt — 100 kw
Research and isotope production	100 kw — 3000 kw
Mobile power units	10 mw* — 300 mw
Stationary power plants	100 mw — 1000 mw

* One mw (megawatt) equals 1,000 kw.

TABLE 3.—PROPERTIES OF REACTOR SYSTEMS

Fuel	Moderator	Coolant	Approximate diameter, height of cylindrical core, ft.
Natural uranium	graphite	H ₂ O	25
Natural uranium	D ₂ O	H ₂ O or D ₂ O	10
Slightly Enriched U	graphite	Na or Bi	8
Slightly Enriched U	H ₂ O	H ₂ O	5
Highly Enriched U	H ₂ O	H ₂ O	1
Highly Enriched U	none	NaK	> 1

level may be adjusted on the basis of economy or other factors, but in general it will remain within specified limits. A reactor may be operated at any power level below its maximum. The neutron flux varies directly with power level and inversely with the amount of fissionable material present. Thus, a research reactor which has a small amount of fissionable material has a relatively high neutron flux even at low power.

b. Reactor Components. The selection of the most suitable combination and amounts of nuclear fuel, moderator, and coolant for a given type of reactor design involves an extensive survey of many possible systems. Particular requirements of the reactor, such as minimum size, high neutron economy, or low

cost, narrows the choice of reactor materials. Some properties of typical reactor systems are shown in Table 3.

c. Size of Core. The size of the reactor core required depends on the specified power level and power density (heat removed per unit volume of core). For each reactor system, there is a minimum size of critical diameter necessary to sustain the nuclear chain reaction. In cases where the required diameter is larger than the critical diameter for heat removal considerations, the excess reactivity is adjusted by adding neutron absorbing material to the core. This may be either a nonproductive absorber, such as cadmium or boron, or a fertile material such as U²³⁸ or Th²³² which will generate new reactor fuel.

The reactor dimensions shown in Table 3 represent typical core sizes. For each system, the reactor dimensions can be varied over fairly wide limits by changing either the degree of enrichment, the concentration of fuel, or the amount of neutron absorbing material present.

d. Power Density. The power density in a reactor depends on the heat removed per unit of fuel and the concentration of fuel in the reactor. The first of these factors, designated as the specific power (and usually stated as kw./kg. fuel), is a function of the design and type of fuel element and the efficiency of the coolant. The second factor, the concentration of fuel, is determined primarily by the ratio of fuel to the moderator, which, in turn, is dictated by the nuclear characteristics of the reactor system.

e. Degree of Enrichment. The amount of fissionable material required to sustain the fission reaction is a function of the size of the reactor core and the nuclear properties of the materials in the core. By using slightly enriched or highly enriched fuel, i.e., uranium containing more than 0.71% U²³⁵, one achieves greater flexibility, especially with regard to the size of the core and choice of materials. The only available sources of enriched uranium in this country are the gaseous diffusion plant at Oak Ridge and others being built. Plutonium or U²³³ produced in the Hanford and other reactors also may be used.

Thus far, the bases for specifying the characteristics of the reactor system have been described. Normally, the nuclear engineer limits his considerations to those systems which have been demonstrated by experience to be most practical and economical. The development of new reactor systems and new types of materials continues, however, and the engineer faces an expanding assortment of systems and materials from which to choose.

The problem of designing a nuclear reactor starts with the establishment of a power level based on the required performance. This is followed by a selection of a suitable reactor system based on considerations of size, power density, and degree of enrichment.

HEAT REMOVAL PROBLEM

For many reactor applications, or for economic considerations, a minimum size core requirement becomes important. This factor, combined with high power level, makes it necessary to design a system with the highest possible power density, or specific power. In such cases, the heat removal from the reactor core and structure becomes the most important engineering problem. A

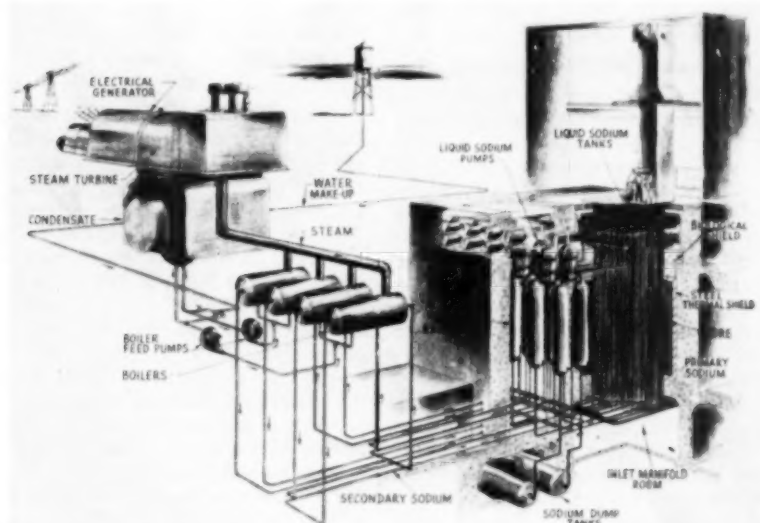


Fig. 1. Conceptual design of nuclear power plant. The primary sodium coolant, which becomes radioactive when passing through the core, is separated from a secondary nonradioactive sodium circuit by heat exchangers. This secondary coolant generates steam in boilers to drive a conventional turbine-generator unit.

solution to this problem involves a consideration of the variables discussed in paragraphs (f) through (j).

f. Type of Coolant. The problem of heat removal from a reactor depends primarily on the type of coolant selected. The major contenders are air, He, H₂O, D₂O, and sodium. Other coolants may have merit for special applications.

The availability of air makes it an obvious choice as a coolant. On the other hand, it is a poor heat-transfer medium, and pumping costs are high. Furthermore, air which is discharged through a stack may require filters since there is a hazard because of the possibility of active material getting into the air stream. In addition, radioactive argon will always be generated in the air coolant.

Ordinary water is particularly attractive for low cost, research reactors. In power reactors, where high temperature operation is necessary, water cooling becomes less desirable because of high pressures required. Water becomes radioactive in a neutron flux and emits gamma rays for a time after leaving the reactor. For this reason, the system must be completely leakproof. In addition, water decomposes into H₂ and O₂ in a field of radiation, and this gas mixture must be diluted or recombined to prevent an explosive mixture from forming. From a nuclear standpoint, water is an efficient moderator, but the hydrogen has a rather high neutron absorption property. For this reason, H₂O as moderator and coolant cannot be used with uranium of natural enrichment. Light water, however, can be used as the coolant with graphite or D₂O moderators.

The use of heavy water as a coolant and moderator is advantageous from the standpoint of neutron economy and because natural uranium-D₂O systems are feasible. The rather high cost of D₂O, however, requires that losses be held to a minimum and results in high capital investments. This means that the decomposition gases must be recombined and provision made for detecting all possible leaks. Hence, a D₂O system is likely to become more elaborate than an H₂O system.

Use of sodium or other liquid metals as reactor coolants (see Fig. 1) is attractive for high temperature operation because of their low vapor pressure and favorable heat-transfer properties. However, the system must be completely leakproof. Sodium handling is extremely difficult because of its high melting point, chemical activity, and radioactivity after exposure to neutrons. All sodium surfaces must be blanketed with inert gases to prevent fires, and all portions of the equipment provided with

TABLE 4.—THERMAL EFFICIENCY OF STEAM PLANTS

Steam Temperature °F.	Saturation Temperature °F.	Pressure, lb./sq.in. abs.	Thermal Efficiency, %
200	198	12	12
400	328	100	23.5
600	417	300	28.7
800	495	660	34.8
1000	593	1465	39.6

heaters to keep the liquid metal from freezing at ordinary temperatures. An elaborate purification system must also be provided to remove sodium oxide and other impurities.

It is obvious that the problem of achieving high power densities in a reactor is not easy to solve since there is no ideal coolant. Moreover, the combined effect of radiation and high temperature operation imposes design limitations not encountered in previous industrial practice.

g. Method of Heat Removal. Cooling can be accomplished in a number of ways, such as by forced circulation, natural convection, boiling, or flash vaporization.

The merits of each method must be considered with respect to the maximum specific power obtainable. While boiling appears attractive because of the small pumping power required, the presence of bubbles in the reactor may introduce undesirable fluctuations in the neutron and power levels. The amount of heat which can be removed by natural convection is limited, but such a system is ideal for low power operation. Flash vaporization may be less attractive than forced circulation since all the liquid pumped is expanded through a large pressure drop which results in high pumping costs.

h. Arrangement of Fuel and Moderator. Reactors are considered to be heterogeneous when the fuel and moderator are separated, that is, arranged in a lattice pattern. An intimate mixture of fuel and moderator is regarded as homogeneous. Though lumping the fuel has some nuclear advantages, this arrangement limits the specific power which may be achieved. For this reason, the design trend, even in solid fueled, heterogeneous reactors, is toward smaller fuel elements or more complete dispersion of fuel.

Since a solution of a uranium salt in H₂O or D₂O is the most practical example of a homogeneous mixture of fuel and moderator, the term homogeneous reactor usually refers to this system. An aqueous solution reactor has many advantages, but they are partly offset by the problem of circulating the highly radioactive fuel solution through external heat exchangers. Though solu-

tion-type and other liquid fuel reactors are still in an early development stage, they show great promise.

i. Type of Fuel Element. The maximum specific power in a heterogeneous nuclear reactor depends on the type and design of the fuel element. Some sort of cladding is usually required to prevent uranium metal from reacting with coolants, and to confine the radioactive fission products. The engineer attempts to reduce the thickness or diameter of fuel elements to avoid excessive internal temperatures, but as he does this, the proportion of cladding material to fuel increases. The cladding material absorption of neutrons increases the problem of neutron economy. In addition, fabrication costs may increase with small fuel elements.

Typical fuel element designs include solid rods, hollow rods, rod bundles, and plates. These may be clad with aluminum, stainless steel, or zirconium.

j. Temperature of Operation. The operating temperature of the reactor, or to be exact, the temperature of the coolant as it leaves the reactor, is an important factor in the economy of nuclear power production since it determines the thermal efficiency of the system. The importance of the outlet temperature is shown in Table 4, which lists thermal efficiency as a function of steam plant characteristics. Efficiencies will vary somewhat from the values given, depending on reheat cycles and other factors. As long as fuel costs are significant, high thermal efficiencies are desirable. With low fuel costs, the need for high steam temperatures depends on the relative investment cost of low and high pressure plants. On this basis, the optimum nuclear plant may not operate at a steam pressure as high as modern coal-fired plants.

k. Design of Shield and Associated Facilities. Having established the requirements of the reactor system and solved the heat removal problem, the nuclear engineer is finally in a position to design the reactor structure, mechanical components, and associated facilities. In stationary reactors, the design of this portion of the system is often considered to be secondary, although such items may comprise the major fraction of the total cost. In mobile reactors, however, the design of the shield and external heat removal system is a problem of equal magnitude to that of the reactor core. Each system has its own peculiar problems which are difficult to present in a generalized design procedure. It should be emphasized, however, that the design of equipment used outside the reactor core is based on materials selected for their physical and mechanical properties alone

rather than on their combined nuclear and physical characteristics. For this reason, external reactor equipment tends toward conventional designs.

Depending on the purpose of the reactor, one or more of the factors just discussed may become overriding. In a mobile power reactor, for example, minimum size and high power density become important. In a plutonium production reactor, efficient use of neutrons is desired. In a stationary nuclear power plant, the primary emphasis is on economic considerations, since the nuclear plants must compete with conventional power systems.

One method of demonstrating technological and economic advances necessary for the development of large-scale nuclear power plants involves a sequence of small experimental plants. The first such plant, the Experimental Breeder Reactor, is being operated at the National Reactor Testing Station in Idaho by the Argonne National Laboratory. A second unit, the Homogeneous Reactor Experiment, has recently been put into operation at the Oak Ridge National Laboratory in Tennessee. The information gained by operating these units will ultimately be embodied in a large scale plant such as that illustrated in Figure 1.

Part II—Designing a Typical Power Reactor

By use of data in Glasstone and Edlund's recently published book, "Nuclear Reactor Theory," (1) one can estimate the nuclear requirements of the various reactor systems given in Table 3. By covering an appropriate range of variables, it is possible to find the optimum conditions for a given application. Rather than repeat the lengthy calculations involved in such an optimization, an arbitrary selection of variables has been made in the following example, to illustrate the engineering approach to the design of a nuclear power plant. While such an arbitrary approach lessens the accuracy of the predicted cost of nuclear power, further refinements are unwarranted in view of the inaccuracies in available cost estimates and lack of knowledge on the ultimate productive capacity and life of reactors. Even an order-of-magnitude estimate of the cost of a nuclear power plant, however, serves to show the possibilities of nuclear fuels compared to conventional fuels.

The assumption is made that a reactor is to be designed to operate at about 250,000 kw. of heat and to produce steam for a conventional turbo-generator unit. Over-all plant efficiencies of about 24% may be expected; hence the full load rating will be about 60,000 kw. of electricity.

TABLE 5.—SPECIFIC POWER VS. FUEL ELEMENT DIAMETER

Rod diam. in.	Specific power/ unit volume B.t.u./hr. (cu.ft.)	Specific power/ unit weight of uranium kw./kg.
0.4	80×10^6	44
0.8	22×10^6	12
1.5	6×10^6	3

Choice of Reactor System

Assume also that the reactor operates with natural uranium and is moderated and cooled by D₂O. For efficient power production, the coolant temperature should be maintained as high as possible consistent with pressure limitations of the system. To operate at coolant temperatures of 500° F. requires pressures around 1,000 lb./sq.in., allowing about 300 lb./sq.in. excess to provide a 40° F. differential temperature to prevent boiling in the reactor.

Specific Power

The maximum specific power obtainable is usually limited by the temperature of the metal within the fuel element. In the case of metallic uranium, this temperature is kept below 1000° F. to prevent excessive thermal stresses and density changes. The maximum metal temperature is given by:

$$t_m = t_c + \Delta t_f + \Delta t_m \quad (1)$$

where,

t_m = maximum metal temperature
(= 1000° F.)

t_c = maximum coolant temperature,
° F.

Δt_f = film temperature rise, ° F.

Δt_m = metal temperature rise, ° F.

It is evident that for coolant temperatures of 500° F. or more, the combined film and metal temperature rise must be equal or less than 500° F., or

$$\Delta t_f + \Delta t_m = 500. \quad (2)$$

Substituting appropriate equations for the film drop and metal temperature drop for solid, cylindrical, fuel rods gives:

$$\frac{q_o r}{2h} + \frac{q_o r^2}{4k} = 500 \quad (3)$$

where,

q_o = heat generated per unit volume of fuel = B.t.u./hr. (cu.ft.)

r = fuel element radius, ft.

h = heat-transfer coefficient, B.t.u./hr. (sq.ft.) (° F.)

k = thermal conductivity, B.t.u./hr. (sq.ft.) (° F./ft.)

For natural uranium metal, $k = 14$

B.t.u./hr. (sq.ft.) (° F./ft.) and for water flowing at 30 ft./sec.

h = approximately 6000 B.t.u./hr. (sq.ft.) (° F.).

Solving the above equation with 0.4-in. diam. fuel rods, the maximum heat production will be 80×10^6 B.t.u./hr. (cu.ft.) or in C.G.S. units, 44 kw./kg.

Values for other diameter fuel rods are shown in Table 5.

Since power production is proportional to neutron density, which changes throughout the reactor because of neutron diffusion, heat generation in the center of the reactor is higher than average. Maximum values will be about two or three times average values. Thus, the average specific power will not be more than 20 kw./kg., even with 0.4-in. diam. fuel elements. On this basis, a reactor to produce 250,000 kw. of heat will require a fuel loading of about 12,500 kg. (13.8 tons) of uranium.

Size of Core

The size of the reactor core is next determined from the ratio of fuel to moderator, which represents the concentration of fuel in the core. For a given amount of fuel, there is an optimum ratio and hence a core size which will give maximum neutron economy. This is, found by nuclear calculations such as those described by Glasstone and Edlund (1). For the reactor system under consideration, the optimum moderator to fuel ratio turns out to be in the range of 30 or 40 to 1 by volume. The weight ratio of D₂O to uranium will be about 2 to 1. The volume of the reactor core to produce 250,000 kw. of heat is therefore about 23,000 l. (812 cu.ft.) which constitutes a cylinder of 10 ft. diam. and 10 ft. high. The power density in this core will be about 11 kw./l. of D₂O.

Design of Shield

The reactor under consideration will generate at full power approximately one billion curies of gamma radiation, equivalent to the radiation which would come from about 1000 tons of radium. The fraction of this radiation that escapes the core, equivalent to the radiation from something like a score of tons of radium, as well as those neutrons which leak out, must be blocked by shielding to protect personnel.

The type of shield required and its thickness are indicated by the calculation that follows. Since there are 3×10^{13} fissions/(sec.) (kw.) at 250,000 kw. there will be 7.5×10^{18} fissions/sec. Each fission produces about 2.5 neutrons and 5 gamma rays. Assuming that 5% of these escape the core, the neutron flux at the edge of the core will be

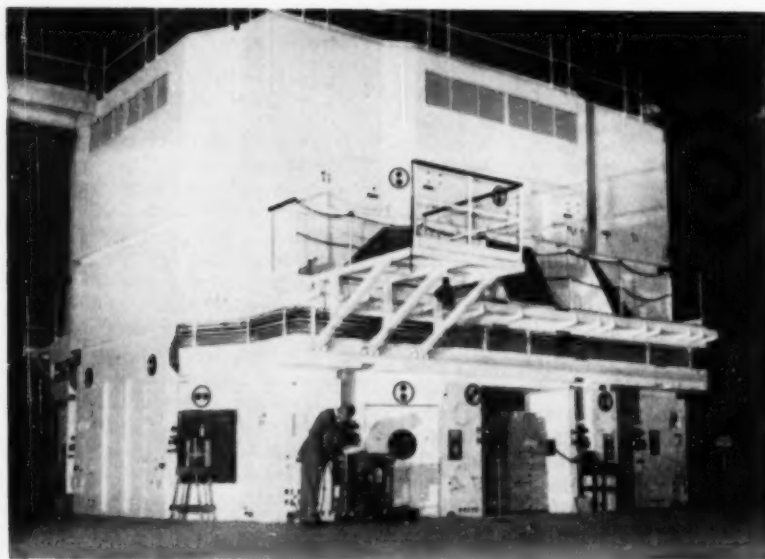


Fig. 2. Materials-testing reactor at National Reactor Testing Station, Idaho. This is used to irradiate materials for use in reactors at high neutron and gamma ray intensities and for general research and development.

about 10^{13} neutrons/(sq.cm.)(sec.) and the gamma flux about 2×10^{13} gammas/(sq.cm.)(sec.). Although concrete is an economic shield material, it has a primary disadvantage in that it does not withstand thermal shock well. Since the absorption of radiation generates heat, there is a maximum neutron and gamma flux to which concrete can be subjected. This means that a supplementary "thermal" shield, as it is called, is usually required to protect the concrete from excessive heat generation. This portion

of the shield must be cooled. To reduce the heat generation in the concrete to a tolerable level requires that the primary radiation must be reduced by a factor of about 10^3 in the thermal shield. An additional factor of 10^3 in the biological shield is required to give levels of 200 gammas or neutrons/(sq.cm.)(sec.) which can be tolerated by humans.

Unfortunately, the requirements for a neutron shield are considerably different from the requirements for a gamma shield. For neutrons, a low atomic

weight material, such as hydrogen, mixed with a high neutron absorber, such as boron or cadmium, makes the best shield. For gammas, however, a dense material, such as lead or iron, is preferred. Hence, one usually selects a compromise material, such as concrete, which is dense and, at the same time, contains hydrogen in the form of water to give neutron moderating and absorption properties. Often it is advantageous to add iron pellets or other dense aggregate to normal concrete to increase the gamma absorption.

It takes about 4 to 6 in. of iron and 6 to 8 in. of water to reduce gamma and neutron fluxes by each factor of 10. Thus, the thermal shield of this reactor should consist of 1 or 2 ft. of iron slabs in layers cooled by a total of 2 ft. of water. The remaining shield would consist of about 9 ft. of ordinary concrete, since 13 in. are required for each factor of 10 reduction in radiation intensity. The reactor with its shield now becomes about 36 ft. in diam., approximately the size of the reactor shown in Figure 2.

In addition to this shield for the reactor proper, additional shielding material will be needed to enclose the primary heat exchanger, pumps, and piping for the cooling water, which becomes radioactive.

Design of Reactor Building

A building to house the reactor would have to cover at least 10,000 sq.ft. of ground area and be about 100 ft. high. It is possible that the trend in nuclear power plants will be toward unhoused

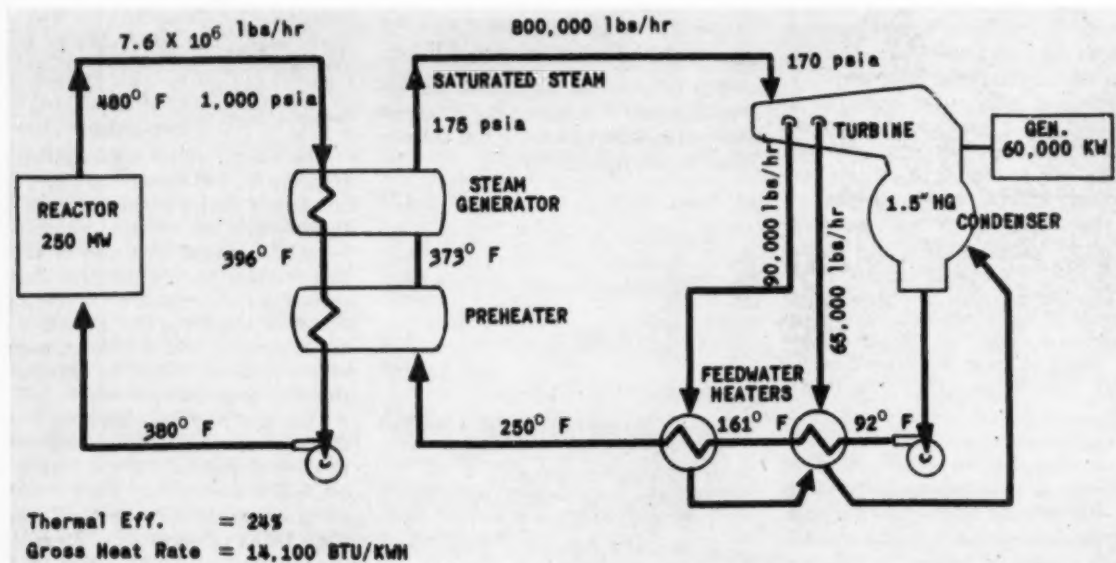


Fig. 3. Nuclear power plant cycle for which heat is furnished by a 250,000-kw. (heat), water-cooled, thermal reactor. The reactor replaces the boiler of a conventional power plant cycle.

reactor structures since the thick shielding can provide protection from the weather. Whether the major structure is exposed or enclosed, provision must be made for sheltering operators and for loading new fuel elements and unloading spent elements.

Design of Power Generating Plant

A reactor operating under the specified conditions will produce about 800,000 lb./hr. of 175 lb./sq.in.abs. saturated steam. This steam is expanded through a low pressure turbine using a single reheat cycle to keep its moisture content below 12%, as shown in the flowsheet (Fig. 3). About 60,000 kw. of electricity is generated with an overall efficiency of approximately 24%.

Economic Considerations

It is possible to establish an order-of-magnitude estimate of the cost of the nuclear portion of the power plant being designed on the basis of the physical size of the reactor core, shield, and associated facilities. Since these unconventional items comprise a minor fraction of the total plant, it is possible to estimate the over-all investment in a nuclear plant almost as closely as in the case of a coal-fired steam plant. Resulting power costs, however, will be strongly affected by factors such as plant lifetime, fuel costs, and operating and maintenance costs which, in the case of the nuclear plant, are difficult to predict.

The cost of the nuclear reactor and primary heat exchangers, also called steam generators, are estimated as in the following:

a. Reactor Core Structure

An estimate of the cost of the reactor core is obtained by assuming costs for a pressurized heat exchanger with 32,000 sq.ft. of heat-transfer surface constructed of stainless steel. Provision for unloading uranium fuel must be included. At \$30/sq.ft., the internal core structure costs about \$1,000,000 on this basis. Adding the cost of a pressure shell, 10 ft. in diam. and 5 in. thick, will double this amount. Instrumentation and services will add another \$400,000.

b. Shield

The volume of the primary shield around the core is about 2,000 cu.yd. Add 500 yd. for auxiliary shielding for piping and equipment outside the core. At \$200/yd installed, the concrete shield will cost \$500,000. The iron thermal shield weighing 150 tons will add about \$100,000.

c. Pumps, Heat Exchangers, and Associated Piping

It is estimated that at the rated reactor power level, a flow of 50,000 gal./min. will be necessary. Experience has shown that the total cost of motors, pumps, and piping amounts to about

\$20/gal./min. of capacity, which makes a total cost of \$1,000,000 for this equipment. For economic reasons, the heat exchangers should operate on lower temperature differences and smaller heat-transfer coefficients than the reactor fuel elements. About 50,000 sq.ft. of heat-transfer surface will be required. At \$30/sq.ft. these exchangers will cost \$1,500,000.

d. Reactor Building

This building contains 1,000,000 cu.ft. and will cost about \$2,000,000 at \$2.00/cu.ft.

An equivalent coal-fired boiler would cost about \$3,000,000 or 40% as much as the nuclear steam plant.

The total investment cost of the nuclear power plant is about \$18,000,000, or \$300/kw. of installed capacity, as shown in Tables 6 and 7. At a fixed charge of 13%/year and at 80% load factor, that part of the cost of power because of fixed charges will be about 5.5 mills/kw.hr. The corresponding power part of the cost because of fixed charges in average, new, coal-fired steam plants of the same capacity is about 3.7 mills/kw.hr. The average fuel cost in coal-fired plants is about \$8.00/ton, or 3.2 mills/kw.hr. Thus nuclear plants which have investment costs as high as shown, can compete only with coal-fired plants if nuclear fuel costs are several mills lower than for coal. The possibility of achieving such a reduction depends on the ability of engineers to develop low cost fuel fabrication methods and fuel elements capable of long life.

In dual purpose units, to produce both plutonium and power, the value of the plutonium might be enough to offset the cost of fabricating and reprocessing fuel elements. Since net fuel costs are negligible, in this case, dual purpose units would be competitive with conventional power plants.

The estimated investment cost of the nuclear power plant shown in Table 7 does not include the initial cost of uranium or D₂O which presumably would be supplied and controlled by the gov-

ernment. Until a definite policy regarding the distribution of such materials is established and cost information made available, it is difficult to estimate the fuel and investment costs in nuclear plants which produce power only.

Breeding

Since excess neutrons from fission will react with the fertile materials, U²³⁸ or Th²³², to produce fissionable Pu²³⁹ or U²³³, respectively, the possibility exists of generating more fissionable material in a reactor as it operates than is burned or consumed. Such a regenerative system would extend the available supply of nuclear fuels by transmutation of the fertile materials. For this reason, it is desirable to have a high regeneration ratio.

When the regeneration ratio exceeds one, the system is said to be *breeding* since it produces more fuel than is consumed. By balancing fuel production and losses, it may be possible to operate such a breeder system under equilibrium conditions in which only U²³⁸ or Th²³² is required for fuel. This prospect is attractive for, in terms of uranium or thorium used up, fuel costs would be less than 0.1 mills/kw. hr.

A study of the efficiency of converting U²³⁸ into Pu²³⁹ is being carried out in the Experimental Breeder Reactor mentioned previously. If successful, breeding gives promise of greater utilization of available uranium and thorium for power production than would be possible in nonregenerative reactors or even in those with a regeneration ratio less than one.

With regard to the cost of nuclear power, however, it is a fallacy to assume that fuel costs in breeder reactors are negligible. First of all, breeding does not eliminate the high fixed charges associated with a large inventory of valuable materials. In addition, breeding systems involve a considerable amount of reprocessing of the fuel to reduce neutron losses by fission fragment capture. These costs may be considerable.

Literature Cited

1. Glasstone, S., and M. C. Edlund, "Nuclear Reactor Theory," D. Van Nostrand Co., New York (1952).

CORRECTION

In the article "Sulfur from Hydrogen Sulfide" by B. W. Gamson and R. H. Elkins (April, 1953, page 203) an error was printed in the caption of Figure 17 on page 215. Jefferson Lake Process should be deleted and the caption should read as follows: Desulfurization of and sulfur recovery from dilute hydrogen sulfide streams.

TABLE 6.—COST OF 250 MW NUCLEAR REACTOR PRODUCING 60 MW ELECTRICAL POWER

Reactor core	\$2,400,000
Shield	600,000
Pumps and heat exchangers	2,000,000
Reactor building	2,000,000
	<hr/>
	\$7,500,000

TABLE 7.—ESTIMATED CAPITAL COST OF 60,000 KW. NUCLEAR POWER PLANT

Reactor	\$7,500,000
Site and facilities	3,000,000
Power generating plant	
Based on \$125/electric kw. of	
installed capacity	7,500,000
	<hr/>
	\$18,000,000

THE SEPARATION OF GASES by Means of Porous Membranes

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Part II. Separation of Gases

From Knudsen's equations governing the molecular flow of gases through a porous membrane, it can be seen that the molecular weight of the gas is an important factor in determining the rate at which a gas flows through a particular membrane. This is the basis for the process of separation of gases by means of porous membranes upon which Graham's law (15) is based.

If the conditions of temperature, pressure, and pore size are such that the mean free path of the gas is large compared with the pore diameter, the flow will be molecular in type, and each component of a gas mixture will flow through the pores independently of the others present. On this basis, Graham formulated his empirical law, which states that the rate of flow of gases varies inversely as the square root of their respective molecular weights.

Applying Graham's law to the case of flow into a vacuum, one obtains the following expression:

$$y_1/y_2 = \frac{x_1}{x_2} \cdot \sqrt{\frac{M_2}{M_1}} \quad (9)$$

where y_1 is the mole fraction of component 1 on the low-pressure side and x_1 is the mole fraction of component 1 on the high-pressure side. It is understood that there is sufficient take-off on the upstream side so that the composition there remains constant.

For the case where the downstream pressure is p and the upstream pressure

is P , the low-pressure composition may be expressed as

$$\frac{y}{1-y} = \sqrt{\frac{M_2}{M_1}} \cdot \left[\frac{Px - py}{P(1-x) - p(1-y)} \right] \quad (10)$$

where y is the low-pressure mole fraction of component 1 and x is the high-pressure mole fraction of component 1. This also is based on a constant upstream composition and thus implies that the fraction of the inlet gas that permeates the membrane is small compared with the amount of gas that is taken off as high-pressure outlet gas. The ratio of the square roots of molecular weights may be replaced by the ratio of experimentally determined permeabilities, or conductances, for cases in which the flow does not conform exactly to molecular flow equations. If the flow is streamline, there would be no separation attained.

Mulliken and Harkins (27) and more recently Weller and Steiner (33, 34, and 35) and Kammermeyer and Ward (20) have derived equations expressing the compositions that may be obtained for conditions under which a finite fraction of the gas is allowed to flow through the membrane.

The Weller and Steiner equations were derived for flow through plastic membranes. The flow mechanism for plastic membranes differs from the flow mechanism in porous materials, but the equations should apply if the flow in the porous material is molecular.

The equations were derived for two cases: Case I involving complete mixing of gases on both sides and Case II entailing no mixing on either side. The distinguishing factor between the two cases is the effective composition on either side of the membrane.

In Case I, the effective high-pressure composition is assumed equal to the composition of the gas leaving the high-pressure side of the membrane, and the low-pressure composition is equal to the composition of the gas leaving the low-pressure side. This gives the relation

$$\frac{x_p}{1-x_p} = \frac{Q_A}{Q_B} \cdot \left[\frac{Px_o - px_p}{P(1-x_o) - p(1-x_p)} \right] \quad (11)$$

where Q_A and Q_B are the permeabilities of components A and B, respectively, x_o is the composition of the gas leaving the high-pressure side, and x_p is the composition of the permeated gas. The permeability, or conductance, is the flow rate per unit pressure difference per unit area.

Combining this equation with the over-all material balance and the balance for individual constituents results in a quadratic equation which enables one to solve for the low-pressure product composition for a given feed composition, pressure and fraction permeated. These equations are

$$N_f = N_o + N_p \quad (12)$$

$$x_f N_f = x_o N_o + x_p N_p \quad (13)$$

$$N_p x_p = Q_A S [Px_o - px_p] \quad (14)$$

Tables 1-3, and Figures 1-5 were run with Part I in the April issue, page 180.

$$N_p(1-x_p) = Q_B S[P(1-x_o) - p(1-x_p)] \quad (15)$$

Letting $\alpha = Q_A/Q_B$ and $\beta = N_p/Q_A S$, Weller and Steiner obtained the following equations:

$$x_p = \frac{\alpha - (P-p)/\beta}{\alpha - 1} \quad (16)$$

and

$$x_o = \frac{(\beta + p)[\alpha - (P-p)/\beta]}{P(\alpha - 1)} \\ = \frac{(\beta + p)x_p}{P} \quad (17)$$

They also let $\gamma = N_o/N_f$ and obtained

$$x_f = \gamma x_o + (1-\gamma)x_p = \\ \left[\frac{\gamma(\beta + p)}{P} + (1-\gamma) \right] \left[\frac{\gamma - (P-p)\beta}{\gamma - 1} \right] \quad (18)$$

This quadratic equation is solved for β and then combined with Equation (17) to give x_p .

In Case II, laminar flow (no mixing) occurs on either side of the membrane. The following equation is derived:

$$\ln \frac{N_o^B}{N_f^B} = R \ln \frac{t_f - B/A}{t_o - B/A} \\ + U \ln \frac{t_f - a + C}{t_o - a + C} + T \ln \frac{t_f - C}{t_o - C} \quad (19)$$

where

$$A = \frac{1}{2} \left[(1-\alpha) \frac{P}{P} + \alpha \right]$$

$$B = AC + \alpha/2$$

$$C = \frac{1}{2} \left[(1-\alpha) \frac{P}{P} - 1 \right]$$

$$R = \frac{1}{2A-1}$$

$$U = [a(A-1) + C]/(2A-1)$$

$$T = \frac{1}{\left[\frac{a}{2} - C \right]}$$

$$i = \frac{1}{1-A-B/C}$$

$$t = -iA \pm [A^2 i^2 + 2Bi + C^2]^{1/2}$$

$$i = \frac{N^A}{N^B}$$

and the subscripts f and o refer to feed and outlet high-pressure gas.

Equation (19) can be solved for any given value of N_p , i , t_o and N_o^B .

The nomenclature of Weller and Steiner has been somewhat modified in this presentation.

Benedict (7) discusses some of the practical aspects of the separation of gases by flow through porous membranes. He points out that gaseous diffusion, or effusion, has the disadvantages of having to be operated at sub-atmospheric pressures and is a separate-stage process. He believes that gaseous diffusion, or membrane diffusion, will be

preferred to thermal diffusion when large volumes of gases are to be separated, so that a small number of large stages may be employed. Benedict also points out that gaseous diffusion requires so much more energy than the conventional methods of separation, such as distillation and absorption, that it will not replace them except in unusual cases.

Keith (22) and Hogerton (17) discuss the gaseous diffusion separation as carried out at Oak Ridge by the Atomic Energy Commission. Keith points out the factors which prevent the theoretical enrichment from being attained: (1) there is back diffusion from the low-pressure side, (2) the flow is not true molecular flow, and (3) there exists at the barrier, or membrane surface, a sluggish gas film. Since it is from this film that diffusion occurs, a certain amount of depletion within the film takes place. This film is analogous to the film encountered in heat transfer and in other types of mass transfer. Keith also states that the most desirable condition from the point of view of plant size and power requirement would be a stage where one half the gas diffused through the barrier and the circulation through any diffusion stage would be many times the net transport of materials from stage to stage.

Apparatus and Procedure

The diagram of the apparatus used for the separation experiments is shown in Figure 6.

The porous glass membrane cell assembly was the same as that used in the permeability determination as described in Part I. The feed gas was supplied to the top of the cell, and the undiffused gas left the cell from the side outlet. The permeated gas left from the bottom end of the cell. Rotameters, used to determine the rates of the permeated gas and the unpermeated high-pressure outlet gas, were calibrated for mixtures of various concentrations of hydrogen and carbon dioxide. The feed-gas rate was obtained as the sum of the two outlet-gas rates. The high-pressure outlet-gas rate (unpermeated gas) was controlled by the valve at the outlet. A Bourdon-type pressure gauge and a pressure regulator valve were used to measure and control the upstream pressure. Gas samples were taken by displacement of saturated sodium chloride solution from sample bottles. All analysis work was performed with conventional or modified Orsat apparatus.

In order to improve the accuracy of the flow-rate measurements, the rates of flow of the respective streams were determined by timing the collection of a definite volume of the gas in a graduated burette. The burette was connected by means of a three-way stopcock to the Orsat apparatus. This set-up permitted the determination of the flow rate and the collection of the gas samples simultaneously and eliminated the task of recalibration of the rotameters for various other mixtures.

Discussion of Results

Separation experiments were made with the following mixtures: H_2-CO_2 , H_2-O_2 , H_2-N_2 , $H_2-O_2-CO_2$.

The data are plotted in Figures 7 to 10. In Figures 7, 8, and 9, the mole

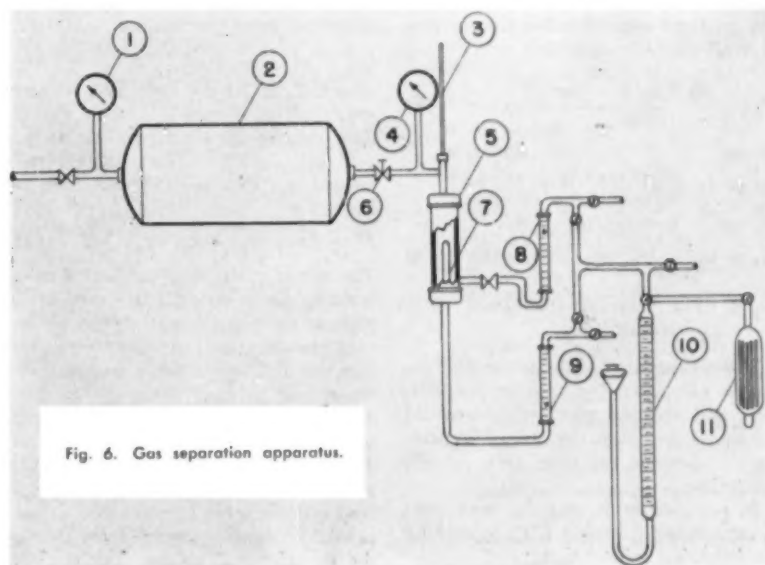


Fig. 6. Gas separation apparatus.

1. 600 lb./sq.in. pressure gauge
2. Gas storage tank
3. Thermometer
4. 100 lb./sq.in. pressure gauge
5. 1 1/4 in. x 8 in. pipe nipple and caps
6. Pressure regulator valve

7. Porous glass membrane
8. Rotameter, high-pressure outlet gas
9. Rotameter, permeated gas
10. Graduated gas burette
11. Absorption pipet

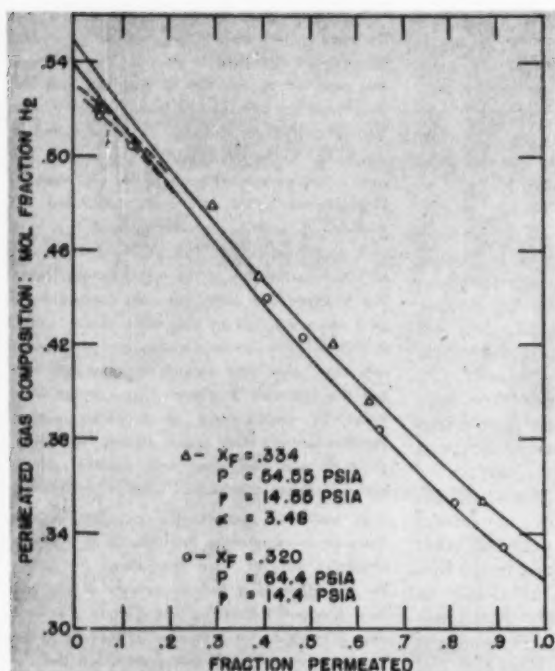


Fig. 7. H_2-N_2 separation by porous glass.

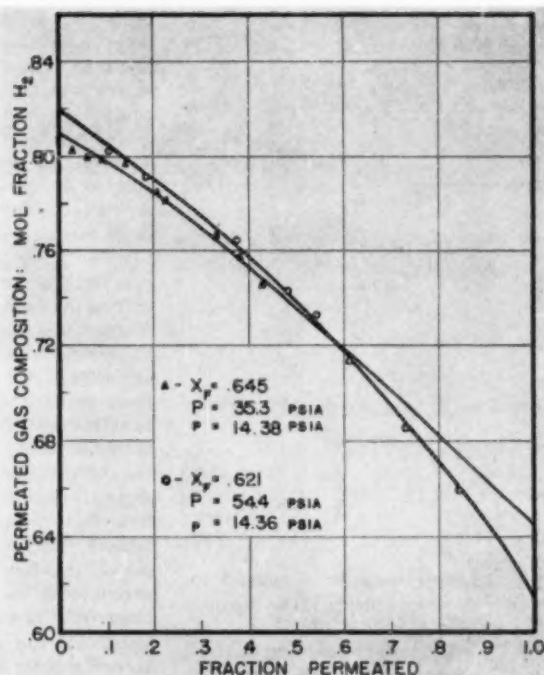


Fig. 8. H_2-O_2 separation by porous glass.

fraction hydrogen in the permeated gas is plotted vs. the fraction permeated, which is defined as the fraction of the inlet feed gas that flows through the membrane.

The solid curves represent the theoretical values as calculated from Equations (12) to (15). These equations may be combined to yield the following expression, which represents a different and perhaps somewhat simplified form of Weller's (33) equation:

$$x_F = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad (21)$$

where

$$a = (\alpha - 1) \cdot [PF + p(1 - F)]$$

$$c = \alpha P x_f$$

$$b = -[P(1 - x_f) + a + c]$$

x_f = mole fraction component A in feed

x_p = mole fraction component A in permeated gas

The composition of the permeated gas can be calculated for a given pressure, feed, and fraction permeated, provided conditions are such that complete mixing is obtained on both sides of the membrane.

In some cases it may be more convenient to use Equation (21) by making the following substitutions:

$$a = (\alpha - 1)p$$

$$c = \alpha P x_o$$

$$b = -[P(1 - x_o) + a + c]$$

where x_o is the mole fraction hydrogen

in the high-pressure outlet gas.

This second form is equivalent to the first form. The theoretical curves in Figures 7, 8, and 9 were calculated from the second form, which involved x_o instead of F . This was done because it was felt that the experimental values of x_o were more accurate than values of F which were calculated from the flow rates. The fraction permeated could be calculated from the relation

$$F = N_p / (N_p + N_o) \quad (22)$$

where N_p is the flow rate of permeated gas, (std.cc.)/(min.), and N_o is the flow rate of high-pressure outlet gas, (std.cc.)/(min.). The fraction permeated can also be calculated from the relation

$$F = (x_f - x_o) / (x_p - x_o) \quad (23)$$

The values of fraction permeated calculated by Equation (23) are used in the plots of the experimental data.

It can be seen from Figures 7 to 9 that the data agree fairly well with the theoretical values. It is to be noted, however, that in one case the experimental values of x_p at low values of F are definitely lower than the theoretical values and that a similar trend may be read into the other graphs. This is indicated by drawing dashed lines through the experimental points. The explanation for this phenomenon is not apparent. It must be pointed out that even though Equation (21) was derived on the basis that there was complete mixing on both sides of the membrane,

it is improbable that such conditions actually exist. Since the flow rates on both sides of the membrane are in the laminar region, there could hardly be complete mixing. The exact effect of the stagnant film mentioned by Keith (23) and encountered in almost all diffusional processes is still undetermined.

It can be concluded that for purposes of calculation either form of Equation (21), derived for complete mixing, may be used with confidence over the range of experimental values found here. It must be kept in mind that the equation represents a theoretical expression based on simplifying assumptions and is not based on the actual mechanism.

Weller and Steiner found Equation (19), the equation based on no mixing, to apply to separation of gases by means of plastic films. The flow in their film pack possibly was different from that in the equipment used in this research.

The values of α used in calculating the theoretical curves were taken as the ratio of the respective permeability constants. In only one case, Figure 7, was there much deviation. An α equal to 3.54 instead of 3.1 was required to give a theoretical curve agreeing with the experimental points. It should be pointed out that the calculated values of x_p are not very sensitive to changes in the value of α but would be quite noticeable in cases where a large number of stages would be required for separation. For a relatively small number of stages, use of either the ratio

Q_A/Q_B or the ratio $\sqrt{M_B/M_A}$ will give satisfactory results when Equation (21) is used to estimate permeated gas compositions.

From Figures 7 to 9 it can also be seen that it would be of advantage to operate with a high-pressure difference, as the increase in separation was appreciable.

For a ternary system, the expression giving the composition of the permeated gas [see Appendix, Equation (16B)] can be shown to be

$$[RTW^2](x_p^A)^3 - [TWP(Q_A x_f^A + Q_B x_f^B) - R(W(Q_A x_f^A + Q_B x_f^B) - Q_A W)](x_p^A)^2 + [UQ_A P^2 x_f^A x_f^B + Q_A P x_f^A (VQ_C P - VQ_C P + TP x_f^A + Q_A W + RW)]x_p^A - (Q_A P x_f^A)^2 = 0 \quad (24)$$

where

$$R = Q_A - Q_B \\ T = Q_A - Q_C \\ U = Q_B - Q_C \\ V = 1 - F \\ W = PF + p - Fp$$

For any given values of P , p , Q_A , Q_B , Q_C , x_f^A , x_f^B , x_f^C , and F , this cubic equation can be solved for the permeated-gas composition x_p^A . Substitution in the equation (see Appendix, Equation 14B)

$$x_p^B = \frac{Q_B P x_f^A x_f^B}{Q_A P (x_f^A - F x_p^A) - Q_A (1 - F) p x_p^A + Q_B (1 - F) p x_p^A + Q_B P F x_p^A} \quad (25)$$

gives x_p^B . The value of x_p^C is obtained by difference.

The derivation of the equations for a ternary system is presented in the Appendix.

The data for the ternary system hydrogen-carbon dioxide-oxygen are shown in Figure 10 as the mole fraction hydrogen in the permeated gas plotted against the fraction permeated F . The line in the figure, calculated from Equation (24), represents the theoretical values of x_p^A . The agreement here is also good.

Summary

Experimentally determined permeabilities were found to deviate from expected behavior, presumably because of adsorbed flow or mobility of an adsorbed layer of gas. Molecular, or Knudsen, flow was found to be the main method of transport.

The separation that was obtained with mixtures of gases agreed fairly well with calculations made using the experimental values of permeability, even though the ratio of experimental permeabilities differed from the theoretical ratio of molecular weights.

The use of the equation presented [Equation (21)] and the experimental permeabilities is considered, at best, a semiempirical method of calculating the

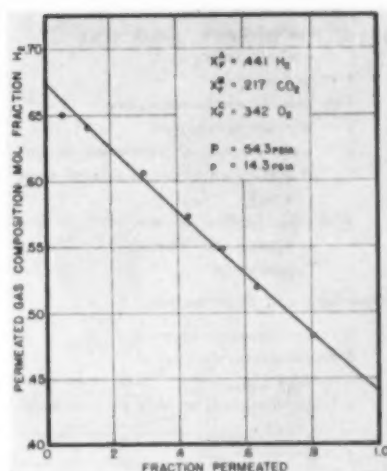


Fig. 10. H₂ - CO₂ - O₂ separation data.

behavior of a single stage of separation. It is believed that these equations do not fully describe the phenomenon of gas separation by porous media.

On the basis of these experiments, porous glass was shown to be a very efficient porous medium for the separation of gases.

These experiments have shown that additional experimental and theoretical work is required on the subjects of adsorbed flow and the mechanism of the separation of gases by means of porous glass.

Acknowledgment

The authors wish to acknowledge the financial support of the Atomic Energy Commission for this research.

Notation

- a = a constant
- b = a constant
- B = a constant
- d = diameter of pore or duct
- f = fraction of molecules striking wall and emitted with random velocity distribution
- F_p = flow rate per unit pressure drop
- F = fraction of feed gas permeating membrane
- K_1 = permeability constant ($Q\sqrt{T}$)
- K_2 = membrane constant ($Q\sqrt{TM}$)
- l = length of pore
- M = molecular weight
- N = gas flow rate, (std.cc.)/(min.), or (moles)/(unit time)
- p = absolute pressure on downstream side of membrane
- P = absolute pressure on upstream side of membrane
- P' = average pressure = $(P + p)/2$
- P_0 = vapor pressure
- ΔP = pressure drop across membrane
- Q = corrected gas permeability, (std.cc.)/(sec.)(sq.cm.)(cm.Hg ΔP)

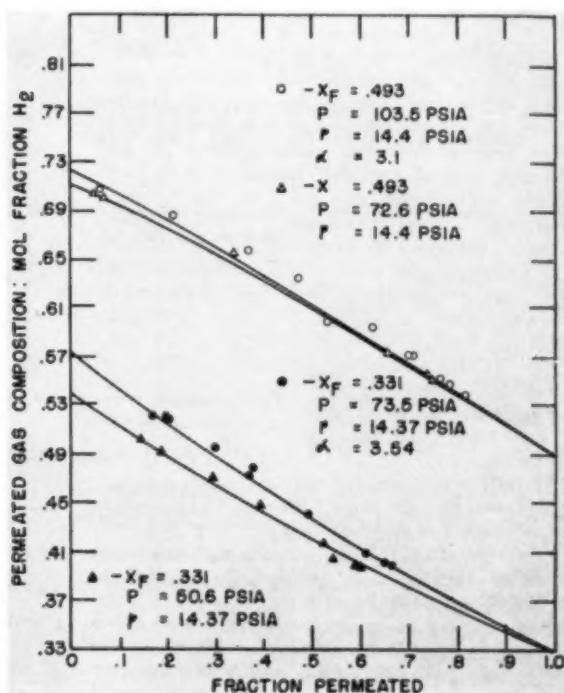


Fig. 9. H₂ - CO₂ separation by porous glass.

r = radius of pore
 r' = average radius
 R = gas constant
 S = area of membrane, sq.cm.
 T = absolute temperature
 x = mole fraction of component in gas mixture on upstream side of membrane
 y = mole fraction of component in gas mixture on downstream side of membrane

Subscripts and Superscripts

A = component designation
 B = component designation
 f = feed gas
 o = unpermeated, or high pressure outlet gas
 p = permeated gas

Greek Letters

$\alpha = Q_A/Q_B$, or $\sqrt{M_B/M_A}$, ratio of permeabilities
 $\beta = N_p/Q_A S$
 γ_s = coefficient of slip
 $\gamma = N_p/N_p$
 η = viscosity

Literature Cited

- Adzumi, Hiroshi, *Bull. Chem. Soc. Japan*, **12**, 199 (1937).
- Adzumi, Hiroshi, *Bull. Chem. Soc. Japan*, **12**, 285 (1937).
- Adzumi, Hiroshi, *Bull. Chem. Soc. Japan*, **12**, 292 (1937).
- Adzumi, Hiroshi, *Bull. Chem. Soc. Japan*, **12**, 304 (1937).
- Barrer, R. M., "Diffusion in and Through Solids," Cambridge Press, London (1941).
- Barrer, R. M., and Grove, D. M., *Trans. Faraday Soc.*, **47**, 826 (1951).
- Benedict, M., *Chem. Eng. Progress*, **43**, 41 (February 1947).
- Brunauer, S., Emmett, P. H., and Teller, E., *J. Am. Chem. Soc.*, **60**, 309 (1938).
- Carman, P. C., *Nature*, **163**, 684 (1949).
- Carman, P. C., and Malherbe, *Proc. Roy. Soc. (London)*, **203**, 165 (1950).
- Dushman, S., "Scientific Foundations of Vacuum Technique," John Wiley, New York (1949).
- Emmett, P. H., and Cines, Martin, J., *Phys. and Colloid Chem.*, **51**, 1248 (1947).
- Emmett, P. H., and DeWitt, Thomas W., *J. Am. Chem. Soc.*, **65**, 1253 (1943).
- Gaede, W., *Ann. Physik*, **41**, 289 (1913).
- Graham, T., *Trans. Roy. Soc. (London)*, **133**, 385 (1863).
- Hodgins, J. W., Flood, E. A., and Dacey, J. R., *Can. J. Research*, **24B**, 167 (1946).
- Hogerton, J. F., *Chem. Eng.*, **52**, 98 (December, 1945).
- Hood, H. P., and Nordberg, M. E., U. S. Patent 2,106,744 (1934).
- Jones, W. M., *Trans. Faraday Soc.*, **47**, 381 (1951).
- Kammermeyer, K., and Ward, H. T., *Ind. Eng. Chem.*, **33**, 474 (1941).
- Kennard, E. H., "Kinetic Theory of Gases," McGraw-Hill, New York (1938).

- Keith, P. C., *Chem. Eng.*, **53**, 112 (February, 1946).
- Klose, W., *Physik. Z.*, **31**, 503 (1930).
- Knudsen, M., *Ann. Physik*, **28**, 75 (1909).
- Loeb, L. B., "Kinetic Theory of Gases," McGraw-Hill, New York (1936).
- Maxwell, J. C., "Scientific Papers, Vol. 2," Cambridge Press, London (1890).
- Mulliken, R. S., and Harkins, W. D., *J. Am. Chem. Soc.*, **44**, 37 (1922).
- Nierenberg, W. A., *Phys. Rev.*, **69**, 259 (1947).
- Pollard, W. G., and Present, R. D., *Phys. Rev.*, **73**, 762 (1948).
- Present, R. D., and Pollard, W. G., *Phys. Rev.*, **69**, 53 (1947).
- Tomlinson, R. H., and Flood, E. A., *Can. J. Research*, **26B**, 38 (1948).
- Weissberger, A., "Technique of Organic Chemistry," Vol. IV; Distillation, p. 540, Interscience Publishers, New York (1951).
- Weller, S., and Steiner, W. A., *Bur. of Mines Rept. No. 3333: Q-152* (Dec. 16, 1949).
- Weller, S., and Steiner, W. A., *J. App. Phys.*, **21**, 279 (1950).
- Weller, S., and Steiner, W. A., *Chem. Eng. Progress*, **46**, 585 (1950).
- Wheeler, A., "Advances in Catalysis, Vol. III," p. 260, Academic Press Inc., New York (1951).

$$N_p x_p^A = Q_A S [P x_o^A - p x_p^A] \quad (78)$$

$$N_p x_p^B = Q_B S [P x_o^B - p x_p^B] \quad (88)$$

$$N_p (1 - x_p^A - x_p^B) = Q_C S [P (1 - x_o^A - x_o^B) - p (1 - x_p^A - x_p^B)] \quad (98)$$

Dividing Equation (78) by (88) and by (98) results in the following equations:

$$\frac{x_p^A}{x_p^B} = \frac{Q_A [P x_o^A - p x_p^A]}{Q_B [P x_o^B - p x_p^B]} \quad (108)$$

and

$$\frac{x_p^A}{1 - x_p^A - x_p^B} = \frac{Q_A [P x_o^A - p x_p^A]}{Q_C [P (1 - x_o^A - x_o^B) - p (1 - x_p^A - x_p^B)]} \quad (118)$$

Substituting for x_o^A and x_o^B from Equations (58) and (68) into Equations (108) and (118), the following two equations are obtained

$$\frac{x_p^A}{x_p^B} = \frac{Q_A \left[P \left(\frac{x_f^A - F x_p^A}{1 - F} \right) - p x_p^A \right]}{Q_B \left[P \left(\frac{x_f^B - F x_p^B}{1 - F} \right) - p x_p^B \right]} \quad (128)$$

and

$$\frac{x_p^A}{1 - x_p^A - x_p^B} = \frac{Q_A \left[P \left(\frac{x_f^A - F x_p^A}{1 - F} \right) - p x_p^A \right]}{Q_C \left[P \left(1 - \frac{x_f^A - F x_p^A}{1 - F} - \frac{x_f^B - F x_p^B}{1 - F} \right) - p (1 - x_p^A - x_p^B) \right]} \quad (138)$$

Solving Equation (128) for x_p^B

$$x_p^B = \frac{Q_B P x_p^A x_f^B}{Q_A P (x_f^A - F x_p^A) - Q_A (1 - F) p x_p^A + Q_B (1 - F) p x_p^A + Q_B P F x_p^A} \quad (148)$$

and from (138),

$$x_p^B = \frac{Q_A (1 - x_p^A) [P (x_f^A - F x_p^A) - (1 - F) p x_p^A] + Q_C x_p^A [p (1 - F) (1 - x_p^A) - P (1 - F - x_f^A + F x_p^A - x_f^B)]}{Q_C x_p^B (P F + p - F p) + Q_A P (x_f^A - F x_p^A) - Q_A (1 - F) p x_p^A} \quad (158)$$

Appendix

DERIVATION OF EQUATION FOR TERNARY SYSTEM

Material balance:

$$N_f = N_o + N_p \quad (18)$$

$$N_f x_f^A = N_o x_o^A + N_p x_p^A \quad (28)$$

$$x^A + x^B + x^C = 1 \quad (38)$$

Let

$$F = \frac{N_p}{N_f} \quad (48)$$

then

$$x_o^A = \frac{x_f^A - x_p^A F}{1 - F} \quad (58)$$

and

$$x_o^B = \frac{x_f^B - x_p^B F}{1 - F} \quad (68)$$

Rate equations:

Equations (148) and (158) are set equal, to eliminate x_p^B . Then let

$$R = Q_A - Q_B$$

$$T = Q_A - Q_C$$

$$U = Q_B - Q_C$$

$$V = 1 - F$$

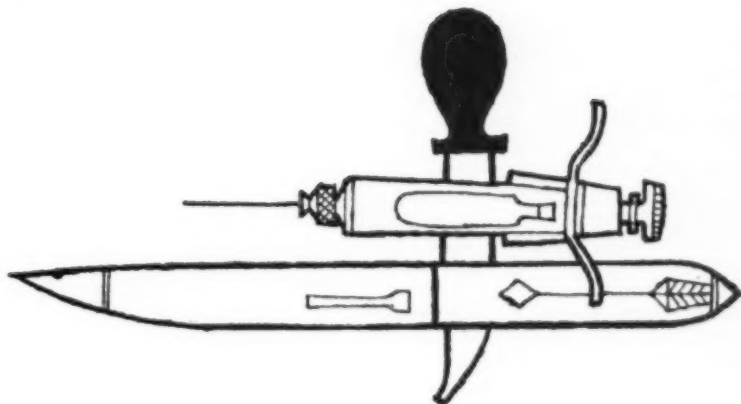
$$W = P F + p - F p$$

Upon algebraic rearrangement, the following equation is obtained

$$[RTW^2](x_p^A)^3 - [TWP(Q_A x_f^A + Q_B x_f^B)] - RW(VQ_C p - VQ_C P - TP x_f^A + Q_C P x_f^B - Q_A W)(x_p^A)^2 + [UQ_A P^2 x_f^A x_f^B + Q_A P x_f^A (VQ_C P - VQ_C p + TP x_f^A + Q_A W + RW)] x_p^A - (Q_A P x_f^A)^2 = 0 \quad (168)$$

For given values of P , p , Q_A , Q_B , Q_C , x_f^A , x_f^B , x_f^C , and F this equation can be solved for the permeated gas composition x_p^A . Substitution in Equation (148) gives the values of x_p^B . The value of x_p^C is obtained by difference.

Controlled Volume Pumping of Minute Flows



R. T. Sheen and A. D. Fell Milton Roy Company, Philadelphia, Pa.

A new design is presented of a controlled volume pump which operates in the range of 3 to 3,000 ml./hr. against pressures from atmospheric to as high as 1,000 lb./sq.in. This metering pump is furnished with a 0.125- or a 0.25-in. diam. plunger on a 1-in. maximum stroke. It may be operated at speeds varying from one to 100 strokes/min.



R. T. Sheen

Robert T. Sheen, consulting chemical engineer and president, Milton Roy Co., Philadelphia, Pa., was identified, early in his career, with Monsanto Chemical Co. in Alabama. In 1932 he became technical director for the W. H. and L. D. Betz Co. in Philadelphia. Subsequently, with his father Milton Roy Sheen, he formed the Milton Roy Co. of which he became president in 1947. He was also founder and president of Chemical Pump & Equipment Corp., New York City, and founder and vice-president of Chemical Pump & Equipment Corp., Cleveland, Ohio. Mr. Sheen received from Lehigh University a B.S. Ch.E. (1931) and Ch.E. (1936).



A. D. Fell, Jr.

Arthur D. Fell, Jr., vice-president since 1951 of the Chemical Pump and Equipment Corporation of Cleveland, Ohio, the northern Ohio sales office of Milton Roy Co., first became associated with Milton Roy in 1940. He was graduated in mechanical engineering from University of Pennsylvania in 1938 and is a registered professional engineer, Pennsylvania, 1946. Mr. Fell is a member of the Instrument Society of America and the American Society of Mechanical Engineers. Mr. Fell served four years in the Navy during World War II.

An increasing need long has been felt by industry for the metered, accurate transfer of liquids in small quantities in laboratory, pilot plant and development projects. Controlled volume pumps have been employed for the accurate delivery of liquids in a normal range of one pint/hr. to as high as 50 gal./min., and have been used as instruments and in conjunction with plant instrumentation (1). A new controlled volume pump has now been designed to meet the need for still lower capacities, and will transfer with instrumental accuracy liquids at predetermined or automatically controlled rates in the range of one to three thousand milliliters (ml) per hour and against pressures as high as one thousand pounds per square inch.

This pump, marketed under the name of miniPump, was first offered to industry in the fall of 1950 after a period of development and laboratory tests. Design objectives and specifications were defined. Such a unit must be small in size, low in capacity and capable of operating against a relatively high pressure, be flexible in its operation for adaptation to different types of drives, be capable of a wide range of capacity adjustment while in operation and be economical in cost. The unit must also be capable of delivering these small quantities with a high degree of repetitive accuracy, preferably to be reproducible within approximately 1%.

The starting point for the design of such a unit was the liquid end in order to incorporate those features that would assure the desired accuracy in

metering action. The step-valve design used in the larger sizes of controlled volume pumps had to be modified and redesigned to meet the required objective.

The step valve design employs a double ball check on both the suction and discharge side of the displacement chamber. This is done to insure positive check valve action so that if one ball check be held off its seat, because of either foreign particles in the liquid being pumped, or because of any slight irregularity in the ball or seat, the chances are the second check would hold and assure a positive check valve action. These two checks in series on suction and discharge must then be designed in such a way as to pass automatically any air or gas that might enter the pump with the liquid and prevent any entrapment of such air or gas in the displacement chamber. A gas bubble in the displacement chamber would alternately compress and expand with reciprocation of the plunger and immediately affect the accuracy of volumetric displacement of the pump.

Minifying the step-valve liquid end design required a steepening of the angle of the passages in the liquid end to assure that gas purging would be automatic. It was also desirable that the displacement chamber be as completely occupied by the plunger as possible at the end of each stroke, short of a machined fit or a piston-type fit. For this reason, it was decided that adjustment of the stroke length to effect variation in capacity must be made entirely on the length of the suction stroke so that the plunger would go to the forward end of the displacement chamber on each stroke regardless of the full length of the suction stroke that may be employed. To assist in accomplishing this objective and also to effect the design of the liquid end that could be manufactured from a precision casting, the liquid end was turned 90 degrees to the plunger axis, and to the design employed on the regular larger pumps.

The necessity for a design on stroke adjustment that would have the plunger finish each stroke at its forward end, dictated how stroke adjustment could be effected. A vernier screw adjustment is employed that will indicate to within 1% of full stroke length an adjustment made while the pump is in operation. The plunger is mounted in a crosshead with a hardened follower machined on the back, driven by a hardened eccentric cam whose movement is limited by the stroke adjustment screw on the suction stroke only (Fig. 1). The cam follower is returned and held against the face of the cam by means of a properly designed spring capable of maintaining positive contact between the face of the cam itself and the cam follower. The cam shaft runs in oilite-type bearings and the entire drive mechanism is contained in an oil bath to insure adequate and proper lubrication of all moving parts and all bearing surfaces.

It has been found that any individual pump can be accurately adjusted from 1% to 100% of its stroke length giving a wide variation of capacity possible by stroke adjustment only. Any individual

pump therefore has a 100 to 1 range of capacity adjustment for a given speed and plunger size. Two plunger sizes are available, namely, $\frac{1}{8}$ - and $\frac{1}{4}$ -in. diam. By selection of plunger size and speed and by stroke adjustment, deliveries of 1 to 3,000 ml./hr. can be obtained with pumps of this design. The liquid ends are so designed that either the $\frac{1}{4}$ - or $\frac{1}{8}$ -in. plungers may be used by simple change of the liquid end and plunger assembly in the field.

Since this unit has its widest use in the chemical industries with a broad range of operating conditions and chemicals handled, it was necessary that

a material of construction be selected that would permit use with a variety of chemicals and that, if possible, a single material of construction be selected. It was also desirable that this material be cast by the precision casting method, also known as the "lost wax" process. Such a method of casting makes possible a mass production of these small castings with a detail and specification of dimensions that result in a saving on machine operations necessary for the final machining of the liquid end. Because of a relatively small amount of metal required for this liquid end, a material of construction that could be

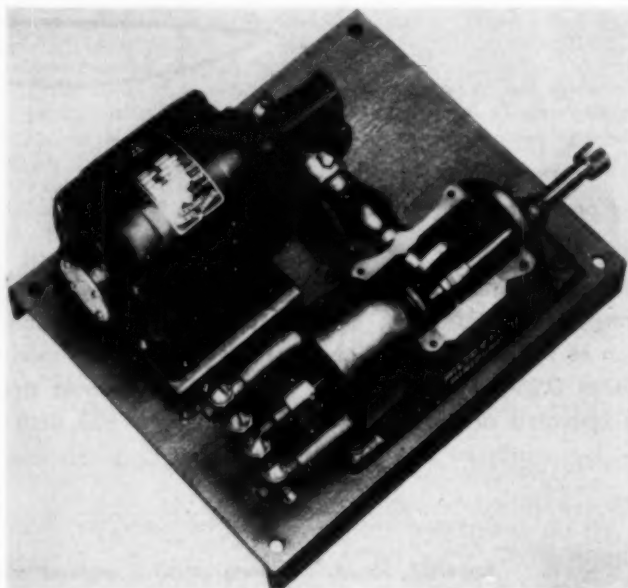


Fig. 1. Cover removed from miniPump to show cam drive and stroke adjustment screw.

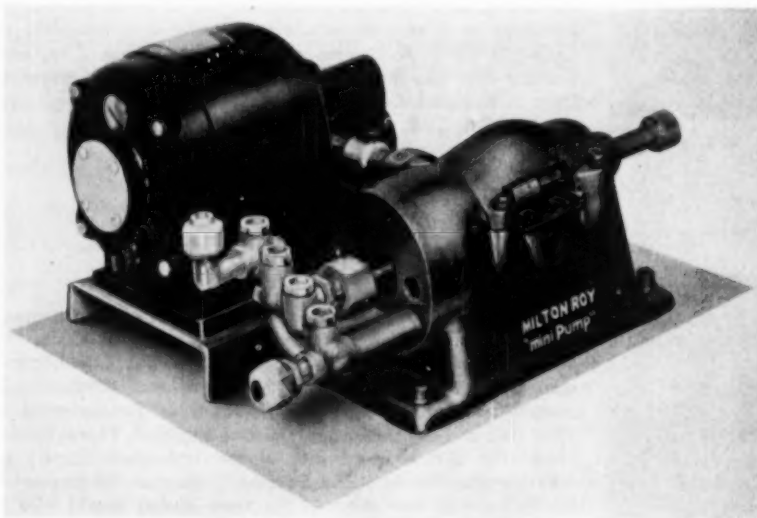


Fig. 2. Motor-driven miniPump.

handled by the precision casting method was selected for maximum possible corrosion resistance. Carpenter No. 20 stainless steel proved to be the most practical solution to this problem. Teflon packing is used in the stuffing box.

Complete flexibility in the selection of drivers for such a unit is desirable. Figure 2 illustrates a standard simplex unit with a Bodine right-angle gearhead motor driver. The over-all size of this unit is 9 in. wide by 12 in. long by 8 in. high and this unit weighs approximately 42 lb.

A variety of speeds is available with this motor driver with three particular speeds as standards to solve the problem for most applications, namely, 29, 57 and 86 strokes/min. These speeds correspond to capacities of 225, 450, and 700 ml./hr. with a $\frac{1}{8}$ -in. diam. plunger and 900, 1800 and 2800 ml. with a $\frac{1}{4}$ -in. diam. plunger.

If explosion-proof drive is required, a General

Electric gearmotor unit is furnished, somewhat larger in size, and with corresponding speeds and capacities. A Thymotrol drive can be used that will give variation of speed possible over a 20-to-1 range by electronic control. Speed variation is by means of a 10,000-ohm potentiometer and is a straight line function of potentiometer setting. This potentiometer may be manually or automatically set by a number of automatic controls permitting automatic control of the quantity of chemical delivered by the pump.

A pneumatic drive by means of an air cylinder can be employed. A $1\frac{1}{2}$ -in.-diam. air cylinder with a 1-in. stroke will give a capacity of 0.13 ml./stroke with a $\frac{1}{8}$ -in. diam. plunger or 0.52 ml./stroke with a $\frac{1}{4}$ -in. diam. plunger. The speed of the plunger on each stroke may be controlled through speed control valves supplied with this pump (Fig. 3). Stroke adjustment on this air operated unit is made while the pump is in operation by means of the adjustment screw on the rear end of the air cylinder, again limiting the length of the suction stroke. The air driven

miniAir pump is operated by a 4-way air valve, admitting air first to one-end of the cylinder and then the other end operates on normal plant air pressure. The 4-way air valve may be actuated by a meter electrically or may be directly driven by a meter located in a main stream flowline to give proportional feed of chemical to the main line. The speed of operation may be timer controlled using any type of programming or automatic control to set the speed and rate of operation.

Other types of drivers such as gas engine, air motor, or pneumatic motor could be utilized.

The first applications for the mini-Pump were found in the industrial laboratory. Many are being used in pilot plant experimental work as a basis for determining whether application of a new process could be justified on a large scale. Commercial applications are made where the metering of this small quantity of liquid is desired with a high degree of accuracy. A typical application of this unit in an automatic process has been made in a large chemical plant in the South on automatic pH control. There a pneumatic positioner was used to actuate the stroke adjustment and to set the length of the stroke from instrument air pressure delivered from a pH meter (Fig. 4). In this installation, the screw on the stroke adjustment was replaced by a positioning rod connected to the pneumatic cylinder so that the stroke adjustment became an integral part of the positioner directly operated to maintain the stroke at required length to give the desired pH value.

An installation is now being made at a Western power company of a similar unit for the addition of odorant to natural gas lines. In this case, however, the driver is an air cylinder, actuated by natural gas. The pump is paced from an electronic type of industrial pacer with the impulse being given to an explosion-proof solenoid operated valve controlling the stroking rate of the pump. The length of stroke is controlled through the pneumatic positioner where the length is set by the rate of flow of natural gas through the main line.

Another variation of the pneumatic positioner to stroke length on the mini-Pump is being made in one of the atomic energy installations where the pump will be employed for sampling of industrial waste. The stroke length of the pneumatic positioner is determined by instrument air pressure from a flowmeter measuring the flow of waste from the plant operating on the height of liquid over a weir.

Certain applications require a multiplicity of streams of different solutions to feed in direct ratio to each other or be held in direct ratio controlled by an external flow. Such an installation was

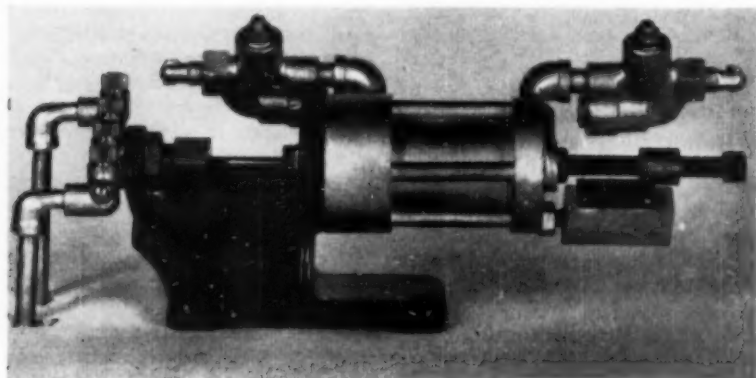


Fig. 3. Air-operated miniPump.

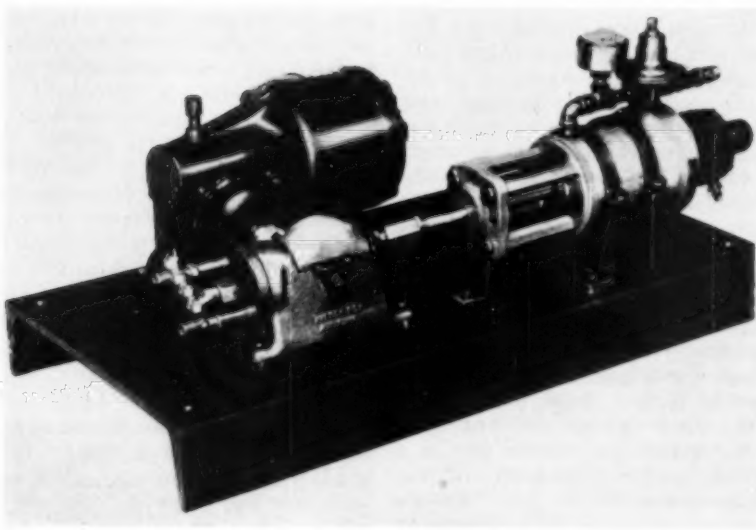


Fig. 4. Automatic capacity regulation by instrument air pressure.

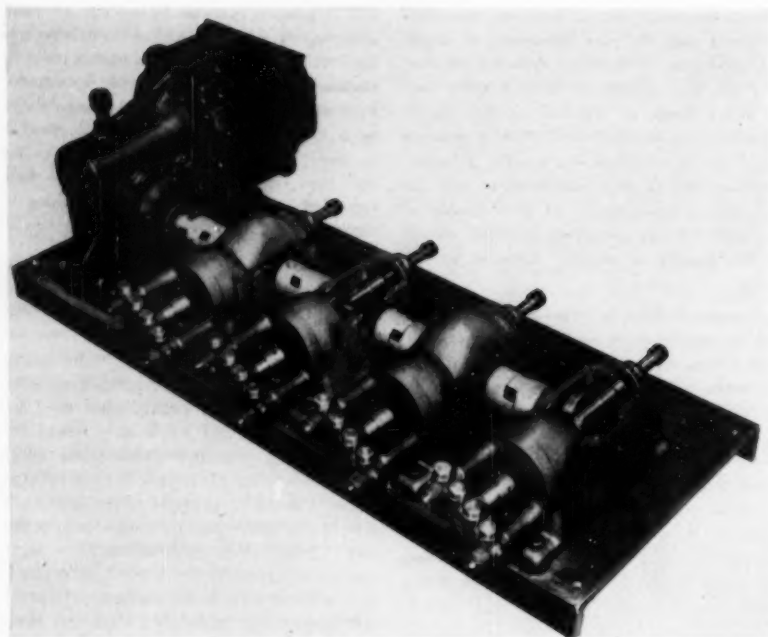


Fig. 5. A four-unit miniPump. Individual capacity regulation of four streams with a common driver.

recently made at an atomic energy plant where four different streams were handled, all of which had to be in fixed ratio one to the other. Occasionally this ratio had to be changed and it was desirable that this be accomplished while the pump was in operation. Figure 5 shows the pump furnished for this problem consisting of a gang arrangement of four miniPumps joined together. Each of the four units handles its own solution and can be individually adjusted to any desired flow by the adjustment screw at the rear of the pump while the pump is in operation. Such arrangement can be manufactured with a total of eight streams merely by extending the base plate and using a double shaft extension motor, and placing an additional four units on the other side of the integral motor gear drive.

Two variables can be employed on a single pump or on a series of pumps arranged in this gang-type design. For example, a Thymotrol motor gear drive may be employed with variable speed control directly in proportion to main line flow. Speed and therefore chemical feed will follow a change in flow over a 20-to-1 range. Length of stroke of the individual pumps or pump may be varied by pneumatic positioning of stroke length, for example, to correct pH value of a highly variable flow of main line liquid. By extracting the variable of flow with motor speed, a highly sensitive pH control will result as the pneumatic positioner then has only to follow

changes in chemical characteristics of the system. Two element controls can also be used with the air actuated pumps. In this case, a flowmeter in the main line recording the flow can regulate the speed of stroking either electrically through a solenoid operated 4-way valve or directly with the air operated rotary valve mounted on the meter and giving a speed of operation in direct proportion to flow through the line. A pneumatic positioner can be adapted to the air pump changing the length of stroke as called for by the variable of chemical characteristics.

In 1948 a controlled volume pump designed to deliver in straight line flow with zero pulsation was introduced (2). It is a characteristic of a normal reciprocating pump to deliver the liquid being pumped by translation of a rotary motion from a drive wheel to a straight line motion of a plunger so that delivery follows a sine curve. Where a duplex pump is furnished, the two cylinders are spaced 180 degrees apart in rotation so that one pump chamber is on suction while the other is on discharge, giving a double sine curve but still resulting in pulsation. The pump introduced was designed as a duplex unit but with the rate of plunger travel controlled by cams. Each cylinder would accelerate to a constant rate of speed over most of the stroke then decelerate with the acceleration and deceleration of the two cylinders overlapping and so designed as to add up to straight line flow. This has

the effect of a plunger traveling continuously forward at a constant rate of speed to get a constant rate of delivery of liquid to process in metered volume. Variation in capacity of such a pump was by means of speed control and the units available on the market at the present time were designed with capacities of 0.1 gal./hr. to 1 gal./min. It was a relatively simple matter to employ cams of similar design for the drive of two cylinders on a miniPump delivering the metered amount in constant flow without pulsation. One application for this specialized design is the addition of vitamins in certain food processing.

A typical application of the air operated miniPump has been made charging electrolyte into batteries. As the batteries are conveyed along a production line, a photoelectric cell actuates a solenoid operated valve which causes the pump to inject a predetermined amount of electrolyte into the battery as it reaches the proper point in the production line. There are many possibilities for this type of application, such as injecting small amounts of liquids into containers or molds on production lines.

In a number of processes, it is desirable to control the strength of a concentrated solution in a range where there is relatively little change in a metered variable such as a pH value, working particularly in stronger concentrations of solutions. A previous paper (1) describes an automatic titration system, employing controlled volume pumps. A continuous sample is taken from process by one controlled volume pump and delivered to a mixing cell. Another controlled volume pump continuously meters to this same mixing cell a standard titrating solution in measured volume so as to neutralize the strong sample from process and to obtain a resulting pH value on a portion of the curve that can be readily measured for control purposes. A pH controller operating from this system then regulates the flow of strong chemicals to the process. In many such applications, the quantity of liquid from the bath and the quantity of standard titrating solution must be held to small volumes. This is particularly the case where the amount of sample going to waste would be a loss of rather expensive sample or expensive titrating chemicals.

Literature Cited

1. Sheen, Robert T., "Instruments," Milton Roy Technical Paper No. 58. (May, 1949).
2. Sheen, Robert T., *Chem. Eng. Progress*, **44**, No. 4, 327 (1948).

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Resistance and Compressibility of Filter Cakes

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PART I

The single useful and proved tool for attacking a cake-filtration problem is the filtration-rate equation. This was developed intuitively from Poiseuille's law for viscous flow in capillaries and has been demonstrated experimentally by many workers, notably Ruth (50), Sperry (52), Carman (11), Lewis (40), and Bonilla (7), as applied to actual filter cakes under conditions of both constant pressure and constant rate filtration. Although written in many forms, the simplest is the general differential form,

$$\frac{dL}{d\theta} = Q = \frac{A g_c \Delta p}{\mu \left(\frac{\alpha w L}{A} + R_m \right)} \quad (1)$$

The most important term in this expression is α , the average specific cake resistance, since it is subject to wide variation even when filtering the same suspension. The understanding of factors controlling the average specific cake resistance of a particular material is very limited, and prediction of α values from physical properties of subsieve particulate solids is generally not possible. The only established fact concerning this important variable is that it varies with filtration pressure (53, 13, 48, 39, and 6) with most chemical cakes and that at filtration pressures below 50 lb./sq.in. this variation can generally be expressed satisfactorily for a particular material and suspension condition as

$$\alpha = \alpha_0 + \alpha' (\Delta p)^s \quad (2)$$

The exponent s , which is constant at moderate filtration pressures, has been termed the "cake compressibility factor," since a positive value of s accompanies the physical compression of the filter cake with increasing filtration pressure.

The term α , average specific cake resistance, has been attacked from a more basic viewpoint in the study of viscous flow through packed beds of particulate materials, by many workers in other fields, notably Carman (12 and 15), Fair and Hatch (29), Fair (28), Hatch (31), Sullivan and Hertel (55), Sulli-

van (54), Keyes (34), Kozeny (35), Rose (47), Coulson (19), Anderson and Warburton (2), Brownell (10), Durwez and Green (24), Ilerall (33), Martin (41), Arnell (3), Furnas (30), Carman and Arnell (16), Carman and Malherbe (17), Wyllie and Rose (57), Emersleben (27), Lea and Nurse (36), Mason (42), Brown (9), and Dodd (23). The most successful outgrowth of this work as applied to particles of small size has been the Kozeny-Carman equation, which was derived for viscous flow in granular beds by the assumption of perfectly random packing of discrete particles and through the use of a mean hydraulic pore diameter expressed in terms of the void fraction and particle specific surface. It was not derived on the assumption of spherical or uniform particles in the bed, it assumes no particular particle shape or size distribution, and no factors for such parameters appear in the equation. As usually written, this equation takes the form

$$u = \frac{\epsilon^3}{(1-\epsilon)^2 K S_o^2} \cdot \frac{(\Delta p) g_c}{\mu L} \quad (3)$$

Theoretically, the constant K is a function of both particle shape and orientation (i.e., the shape of cross section available for flow) and the ratio of length of actual flow path to cake thickness; this was demonstrated experimentally by Carman (12) and later by Sullivan and Hertel (55), Sullivan (54), and Coulson (19) for beds with oriented packings. For random packing of in-

compressible beds (i.e., beds or cakes having a constant cross-section porosity from top to bottom), $K = 5 \pm 10\%$ has been demonstrated experimentally for spherical and nonspherical particles by Carman (15), Fair and Hatch (29), Hatch (31), Lea and Nurse (36) and Blaine (5). The work of Carman using liquid permeability measurements verified this for particles down to 5μ diam. and showed that this value held for mixed beds of different particles. The relative constancy of K for these cases was probably a result of the very randomness of packing within the bed. Little work has been done with liquids flowing through beds of subsieve particles and practically none with particles of ultimate size less than 5μ diam. The ultimate particle size of many materials handled by cake filtration falls well below 5μ , and in general these constitute the class of materials said to form compressible filter cakes.

Considering the cake alone, the filtration-rate equation (1) may be combined with the Kozeny-Carman relationship (3) and written as:

$$Q = \frac{\epsilon^3 \rho_s}{(1-\epsilon) K S_o^2} \cdot \frac{A (\Delta p) g_c}{\mu \left(\frac{W L}{A} \right)} \quad (4)$$

This combination results in expressing the average specific cake resistance α in terms of cake properties,

$$\alpha = \frac{(1-\epsilon) K S_o^2}{\epsilon^3 \rho_s} \quad (5)$$

The experimental difficulties in applying this approach to compressible cakes of very small particles, using data collected from actual filtrations, are considerable. These difficulties arise from the fact that in filtration of compressible cakes the mechanical pressure stress on cake particles varies through the cake depth, causing a variation in cake porosity and specific resistance through the depth of the deposited cake (6, 48, and 13). Thus the term α in the filtration equation is defined as an average specific cake resistance and would necessarily have to be expressed in Equation (5) in terms of average porosity. A simple method of determining the correct average-porosity value from filtration data is not apparent. Curve 1 of Figure 3 illustrates this variation in cake porosity and mechanical-pressure stress through the filter-cake thickness. These data were obtained by sectioning of an actual filter cake and direct measurement of section porosity.

The varying porosity and mechanical pressure stress that occur in compressible filter cakes result from the fact that the hydraulic-pressure drop across the

will be discussed in detail in Part II of this paper.

In many respects the condition of a wide variation in porosity throughout cake depth is unique to the filtration of chemical cakes. Thus with cores of earth taken for permeability measurement in oil-well work (44 and 45), the porosity is relatively uniform, since it was established by the weight of earth above it and is unaffected by the relatively small hydraulic-pressure drop across it during permeability measurements. Also, in conventional air- or liquid-permeability measurements to determine the specific surface of fine powders, it is common practice to compress the powder slug mechanically before making the permeability measurements; the hydraulic-pressure drop during measurements is kept negligible compared to the initial compressive pressure, resulting in nearly uniform porosity throughout the thickness of the bed (17). In permeability measurements on beds of sieve size or larger particles, the compressive effect resulting from fluid flow is very small even for high flow rates.

of cakes of a single material.

The experimental work reported in this paper initiates a direct attack on the nature and variation of specific cake resistance α_p through the development and extensive application of a compression-permeability technique for studying cake properties. Simply stated, this method involves the measurement of average filter-cake porosity ϵ and average specific cake resistance α under conditions of uniform applied pressure stress, for which α_p and ϵ_p the corresponding point values, are essentially constant throughout the cake structure. For this case Equation (5) becomes

$$\alpha_p = \frac{(1 - \epsilon_p) K S_o^2}{\epsilon_p^3 \rho_s} \quad (6)$$

and S_o may be calculated directly from measured data. Analysis of this approach has shown that with the knowledge of variation of α_p and ϵ_p with compressive pressure p_s , which would result from such a study, it should be possible to calculate the average specific cake resistance α for any desired conditions of Δp_c in actual filtration. For the simple case of pressure filtration on a flat

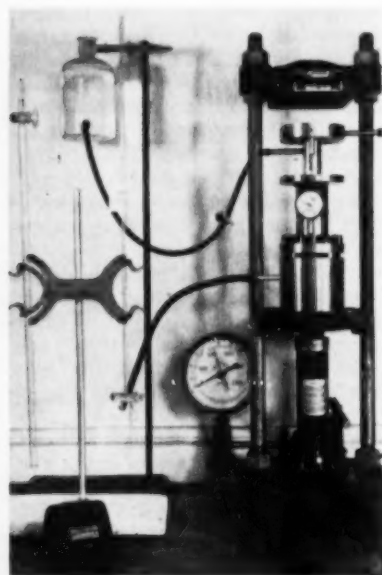


Fig. 1. (a left and b right) Modified compression-permeability cell and set-up counterbalance and weights used for 0- to 30-lb./sq.in. compressive pressure. Carver hydraulic press used for 30- to 2700-lb./sq.in. compressive pressure.

cake is the major force giving rise to pressure stress within the cake. For the case of pressure filtration on a flat vertical surface, the sum of the mechanical-pressure stress at any point within the cake and the adjacent hydraulic pressure (referred to the filtrate pressure at downstream side of cake) is equal to the hydraulic-pressure drop across the cake. For this simple case the average specific cake resistance becomes independent of cake thickness. This is not true, however, for more complex cases, which

Method of Attack

In view of these factors, a method whereby compressible filter cakes having uniform porosity through their depth could be formed and their permeability and porosity measured as a function of mechanical-pressure stress would appear to be a practical approach to the application of granular-bed theory to compressible filter cakes. This approach has been suggested by Heertjes (32), Miller (43), and Ruth (49), and the last named employed this attack in a study

vertical filtering surface, this involves numerical integration and solution of

$$\int_0^{p_2 - p_1} \frac{dp_s}{\alpha_p} = \frac{p_2 - p_1}{\alpha} \quad (7)$$

using compression-permeability data for $1/\alpha_p$ vs. p_s . The development of this equation and the equations required for use of compression-permeability data to solve more complex filtration cases, involving compressive pressures other than those resulting from friction loss in

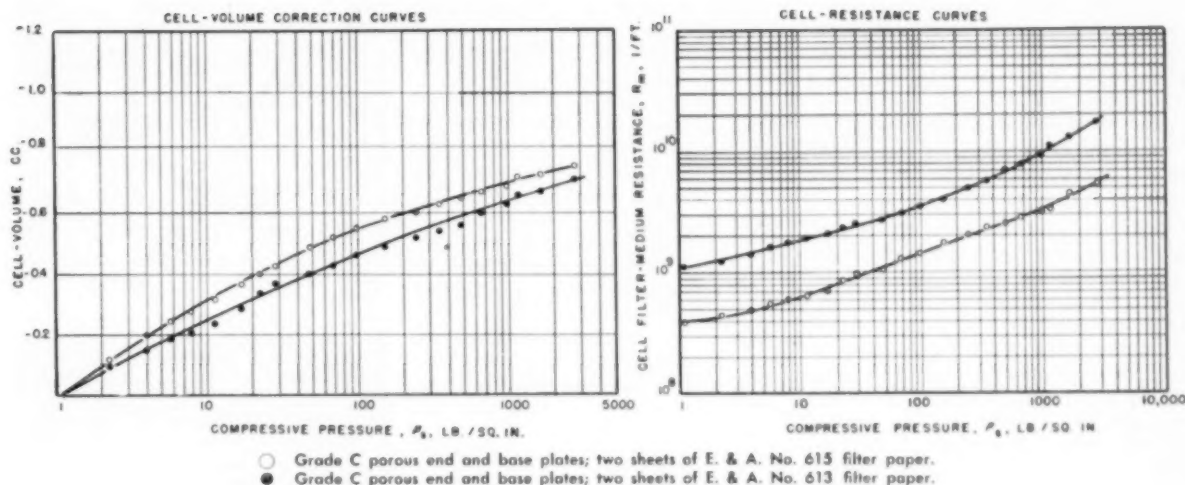


Fig. 2. Blank compression-permeability run data.

flow through cake, is given in Parts II and III of this paper.

Equipment

Figure 1 shows assembled and disassembled views of the compression-permeability cell used in this work. The cell consists essentially of a base with porous drainage plate, a 1.5-in. I.D. hollow cylinder with dial-gauge micrometer, and pistons with porous ends. Mechanical pressure was applied to piston by weights up to 60-lb. load, while a Carver press provided loads up to 5,000 lb. In later work the stainless-steel piston was counterbalanced for compressive pressures down to 1.1 lb./sq.in., instead of using a lighter Lucite acrylic resin piston for low-pressure measurements. This avoided disturbing the cake for piston changes during the run and gave more consistent results. These pistons and base plates were of Grade C porous stainless steel backed by a heavy 8-mesh screen supported by a machined drainage area, the entire assembly being removable in each case. The blank-run correction curves for the cell with either E. & A. No. 615 or 613 filter papers, given in Figure 2, provided means for correcting for cell flexure and filter-base compression as well as for cell-base and piston-end resistance.

Experimental Procedure

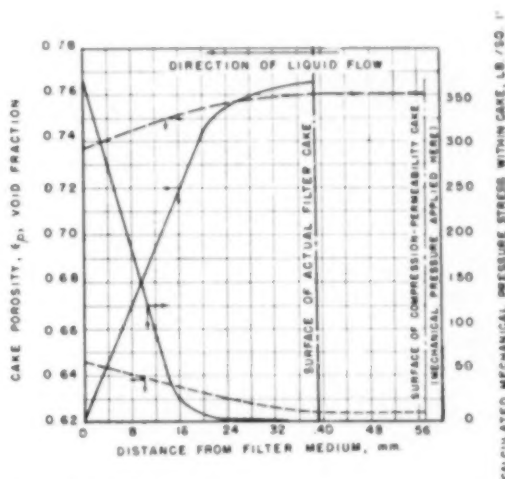
The seventeen materials used for study were examined by several methods other than the compression-permeability method, in order to obtain as much information as possible concerning their physical properties. The materials in dry form were examined under the electron microscope, and the photomicrographs of Figures 4 to 7 were taken to establish size and shape of ultimate particles. Nitrogen-adsorption measurements were also made, and specific surface values were calculated for each material, employing the Brunauer-Emmett-Teller method. Air-permeability measurements were made on the dry materials in most cases, using the Fisher subsieve size, and the corresponding specific

surface was calculated for each, by use of the method and slip-flow correction presented by Arnell (4), and by Carman and Arnell (16), employing a slip factor, $Z = 3.5$. Data on the various materials are shown in Table I.

In general, the suspensions examined contained about 50 g./liter solids; higher concentrations were employed with high-density materials, such as carbonyl iron and tungsten. Suspensions were made up in distilled water or 0.01 molar electrolyte solutions in most cases, although several were plant suspensions of filter feed, and exact electrolyte content was not known. Freshly made suspensions were mechanically agitated 30 min., aged about 1 hr., and used for compression-permeability and comparative-filtration measurements. Suspensions of

seventeen different particulate materials were prepared in various degrees of flocculation, and resulting filter-cake properties were studied.

In making the compression-permeability measurements for this study, the suspension was introduced into the cell cylinder in aliquot portion, and a saturated cake was deposited over the filter paper on the bottom drainage area by applying a slight vacuum of 1 in. Hg under the drainage area. After cake deposition, filtrate was added to the cylinder until the space above the cake was filled. Then a piston with filter paper over its end was inserted into the cylinder and allowed to sink onto the cake surface, thus applying mechanical pressure directly on the cake. Filtrate from a constant-head source (20 to 60 cm. of fluid head) was passed through the



Cake deposited from 5% aqueous suspension of Snow Top superlight CaCO_3 , pH = 9.8

I—Actual filter cake deposited at 350 lb./sq.in.; hydraulic filtration pressure drop.

II—... Compression-permeability cake subjected to 350 lb./sq.in. mechanical pressure (cake was unusually thick (7 to 23 mm in usual test) to permit accurate sectioning).

Fig. 3. Variation of porosity and internal pressure stress within cakes.

cake at each increment of applied mechanical pressure, with filtrate-collection rate determined using a 5-ml. microburette and cake thickness determined from micrometer reading. The blank-run correction curves of Figure 6 were applied to these data and values of a_p , ϵ_p , and S_o vs. p_c calculated. Example data and calculations for Talc C are shown in Table 2.

For this cell design, the cell and filter-medium resistance was about 1% of the total resistance with the flocculated calcium carbonate cakes used and less with more difficultly filterable cakes. In all cases, the cake thicknesses used were within the limits of 23.0 and 7.0 mm. over the entire compression cycle, the cake diameter being 38.1 mm. Uniformity of mechanical-pressure stress within the cake under compression in the cell was checked by sectioning a calcium carbonate cake after it had been subjected to 350 lb./sq.in. mechanical pressure and by direct measurement of section porosity. In order to improve the measurement accuracy in sectioning, a cake of 57-mm. final thickness was used instead of the cakes of 7- to 23-mm. thickness employed in actual compression-permeability measurements. The results show that if the thickness-to-diameter ratio for the compression-permeability cake does not exceed 0.6, the effect of wall support and bridging is negligible, and the porosity and pressure-stress distribution within the compression-permeability cake are uniform. Thus Figure 3 shows that the over-all porosity and pressure-stress variations within the 57-mm.-thick compression-permeability cake were about 12% of that experienced in an actual filter cake deposited at 350 lb./sq.in. but that, over the 23 mm. of cake thickness directly below the piston (34 to 57 mm. from filter medium), the variations in porosity and pressure stress within the compression-permeability cell were less than 1%. This shows that porosity and pressure stress were essentially constant with the 7- to 23-mm.-thick cakes used for the usual compression-permeability runs.

Most permeability measurements fell in the range of 0.020 to 0.400 cu.cm. of filtrate collected in 50 to 500 sec. depending on material and degree of consolidation. Reynolds numbers during permeability measurements ranged from 10^{-2} to 10^{-4} , again depending on material and degree of consolidation, decreasing as consolidation proceeded with each material. After each increase in compressive pressure, sufficient time was allowed for the cake to reach an equilibrium consolidation, and permeability measurements were made only when no further consolidation was noted. The time between successive permeability measurements varied from 2

to 5 min. for materials showing little or moderate compressibility to 10 to 15 min. with very fine and highly flocculated materials showing a high degree of compressibility. The total volume of filtrate passed through the cake during a complete series of compression-permeability measurements on a single material was very small and never exceeded 10 cu.cm. No filter or electroviscous effect was noted, and individual permeability measurements were entirely reproducible after equilibrium cake porosity was attained.

In the case of both flocculated and dispersed calcium carbonate and titanium dioxide suspensions, duplicate runs were made on samples of similar but separately prepared suspensions. These duplicate runs showed good reproducibility of data even with different initial cake thicknesses, provided thickness to diameter ratio of 0.6 was not exceeded.

Discussion of Results

FILTER-CAKE PROPERTIES

Figure 4 shows electronmicrographs of three spherical and two irregular materials used. The Dow polystyrene latex is of nearly uniform size, 0.44 μ diam., and, as suspended in 0.01 molar aluminum sulfate, it was highly flocculated. The SF-grade carbonyl iron was in range of 0.25 to 5 μ diam. with a surface average diameter of 2.15 μ , calculated from particle-size distribution obtained by sedimentation. The E-grade material was in range of 1 to 10 μ diam. with surface average diameter of 5.7 μ , calculated from size distribution. The UT-238 tungsten was irregular; its surface average diameter was 0.4 μ from nitrogen-adsorption measurements. Talc C was very irregular, being composed of thin plates of irregular size (0.5 to 10 μ), which resulted in a large surface per unit volume and a surface average diameter of 0.19 μ as measured by nitrogen adsorption. The carbonyl iron powders as suspended in 0.01 normal sodium hydroxide were slightly flocculated, while UT-238 tungsten suspended in 0.01 normal sodium hydroxide and Talc C suspended in 0.01 molar aluminum sulfate were highly flocculated.

Figure 8 shows results of the compression-permeability study of these materials. These are presented as the variation in specific cake resistance a_p and cake porosity ϵ_p with compressive pressure p_c in plots a and d. Plot b shows effective specific surface S_o calculated from a_p and ϵ_p using Equation (6) (assuming $K = 5$, as for random packed beds) as a function of cake porosity ϵ_p . Plot c shows physical compressibility $\Delta v/(\Delta p_s v_o)$ vs. compressive pressure p_c for the cakes studied.

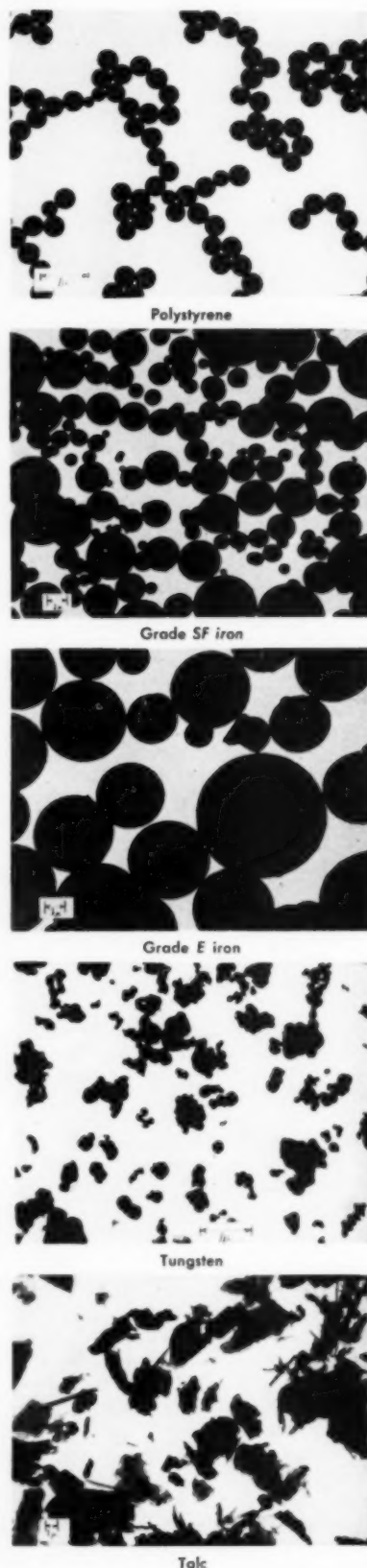


Fig. 4. Electronmicrographs of materials tested.

TABLE 1.—MEASURED SPECIFIC SURFACE VALUES FOR MATERIALS EVALUATED

Material	Measurements on dry powder			Suspension conditions	Liquid compression permeability	Effective S_o † sq.cm./ cu.cm. solid
	Fisher sub-sieve sizer*	Nitrogen adsorption				
	ϵ_v void fraction	S_o sq.cm./ cu.cm. solid	S_n sq.cm./ cu.cm. solid			
Dow polystyrene latex, 580G, lot 4	0.37	109,000	114,500	0.01 M $Al_2(SO_4)_3$ 48g. solid/liter	0.875 0.442-0.373	52,600 163,000
Carbonyl iron powder, grade E **	0.456	12,480	17,900	0.01 N NaOH 225g. solid/liter	0.457 0.401	14,300 16,500
Carbonyl iron powder, grade SF †	0.446	26,700	37,400	0.01 N NaOH 225g. solid/liter	0.423 0.356	32,200 33,700
Talc C powder	0.713	130,000	315,000	0.01 M $Al_2(SO_4)_3$ 50g. solid/liter	0.83 0.44 0.34	123,000 315,000 410,000
Tungsten powder, GE, grade UT-23B	0.766	57,400	149,000	0.01 N NaOH 315g. solid/liter	0.810 0.569 0.49 (extrapolated)	67,000 127,000 149,000
Superlight Snow-Top, calcium carbonate	0.702	72,400	162,000	Dist. Water 50g. solid/liter	0.779 0.563 0.48 (extrapolated)	77,200 128,500 162,000
				0.01 M $Na_3P_2O_7$ 50g. solid/liter	0.692 0.544	104,000 163,000
Ti-Pure R-110, titanium dioxide	0.714	208,500	337,000	Dist. Water 50g. solid/liter	0.772 0.572	201,000 261,000
				0.01 M $Na_3P_2O_7$ 50g. solid/liter	0.611 0.504	285,000 274,000
E. & A. Koolin	0.522	82,500	173,000	0.01 M $Al_2(SO_4)_3$ 50g. solid/liter	0.577 0.344	114,200 160,000
				0.01 M $Na_3P_2O_7$ 50g. solid/liter	0.568 0.352	314,000 278,000
G-60 Darco, activated carbon	0.789	113,300	12,300,000	0.01 M $Na_3P_2O_7$ 50g. solid/liter	0.83 0.65	60,000 1,100,000
Iron blue pigment	0.668	60,000	841,000	Plant filter feed slurry	0.943 0.638	1,120,000 1,350,000
Fine ilmenite dust, TFE-4	0.647	105,500	164,000	0.01 M $Al_2(SO_4)_3$ 100g. solid/liter	0.862 0.503 0.39 (extrapolated)	82,000 131,000 164,000
Type A Linde alumina	0.84	62,500	252,000	0.01 M $Al_2(SO_4)_3$ 50g. solid/liter	0.87 0.84 0.68 0.57 (extrapolated)	43,000 59,000 200,000 252,000
Standard Super-Cel	0.805	57,000	114,000	Dist. water 50g. solid/liter	0.843 0.72	73,000 135,000
Solka Floc BW-200	0.696	12,500	12,600	0.01 M $Al_2(SO_4)_3$ 50g. solid/liter	0.835 0.55 0.34	1,500 15,000 65,000
Type A zinc sulfide suspension	.....	.....	.....	pH = 9.10	0.898 0.794	252,000 937,000
Type B zinc sulfide suspension	.....	.....	.....	pH = 9.07	0.890 0.730	588,000 2,400,000
Fine silica	.....	.....	.....	Plant filter Feed susp.	0.978 0.907	876,000 7,500,000

* Corrected for slip flow

† Assumed $K = 5$ ‡ $S_o = 136,000$ sq.cm./cu.cm. solid as calculated from electronmicrograph.** $S_o = 10,450$ sq.cm./cu.cm. solid as calculated by sedimentation measurement of size distribution†† $S_o = 27,800$ sq.cm./cu.cm. solid as calculated from sedimentation measurement of size distribution

TABLE 2.—TYPICAL COMPRESSION-PERMEABILITY RUN DATA

Suspension of 50g. Talc C/liter
0.01 M $Al_2(SO_4)_3$
Grade C porous stainless-steel base and piston end plates

Total piston press., p_{12} lb./sq.in.	Measured cake vol., V_{cc} cu.cm.	Corrected cake* vol., V_{cc} cu.cm.	Corrected cake porosity, ϵ_p void fract.	Specific cake vol., cu.cm. cake cu.cm. solid	Specific void, cu.cm. voids cu.cm. solids	Average fluid head cm. filtrate	Measured flow rate cu.cm./ sec./cm. head	Filtrate viscosity, cp.	Total resistance, R , 1/ft.	Corrected a_p † ft./lb.	ϵ_p $1 - \epsilon_p$	$\frac{1}{1 - \epsilon_p}$	$\frac{\Delta v_c}{\Delta p v_c}$ sq.in./lb.	Effective specific surface, S_s ‡ sq.cm./ cu.cm. solid	Effective K value of Kozeny- Carman equation**
1.10	18.50	18.50	0.856	6.88	5.90	21.3	2.88×10^{-4}	0.854	1.38×10^{11}	1.057×10^{11}	4.52	6.95	1.63	131,000	
1.67	15.92	16.00	0.833	5.95	4.96	21.3	2.64	0.854	1.505	1.16	3.48	5.98	0.955	121,000	5.07
2.23	14.44	14.56	0.815	5.42	4.42	21.3	2.21	0.854	1.80	1.39	2.92	5.40	0.342	121,000	5.07
3.37	13.33	13.51	0.801	5.04	4.03	21.3	1.83	0.854	2.17	1.67	2.59	5.02	0.342	124,800	5.37
4.50	12.62	12.84	0.791	4.78	3.78	21.3	1.55	0.854	2.56	1.97	2.37	4.78	0.220	129,700	5.82
5.65	12.18	12.43	0.783	4.63	3.62	21.3	1.46	0.854	2.72	2.10	2.22	4.61	0.165	129,700	5.82
7.9	11.55	11.83	0.772	4.41	3.40	21.3	1.22	0.854	3.26	2.51	2.01	4.39	0.099	134,800	6.27
11.3	10.81	11.14	0.759	4.15	3.14	21.3	1.01	0.854	3.93	3.03	1.82	4.14	0.0755	140,800	6.90
17.1	10.16	10.54	0.745	3.93	2.92	21.3	0.836	0.852	4.76	3.67	1.62	3.92	0.0385	146,000	7.40
22.7	9.71	10.12	0.734	3.78	2.77	21.3	0.732	0.852	5.44	4.19	1.49	3.78	0.0270	150,000	7.78
28.3	9.32	9.75	0.724	3.63	2.63	21.3	0.642	0.852	6.20	4.78	1.37	3.62	0.0245	154,000	8.21
47.9	8.59	9.08	0.705	3.38	2.38	21.3	0.478	0.845	8.40	6.46	1.19	3.39	0.0127	166,000	9.45
68.7	8.06	8.58	0.688	3.19	2.20	42.6	0.384	0.845	10.40	8.04	1.08	3.21	0.00897	176,500	10.8
96.5	7.49	8.04	0.666	2.99	2.00	42.6	0.299	0.843	13.45	10.35	0.866	3.00	0.00723	181,500	11.4
152	6.82	7.40	0.637	2.76	1.76	42.6	0.213	0.841	18.9	14.55	0.754	2.76	0.00429	198,000	13.7
243	6.09	6.60	0.593	2.46	1.46	42.6	0.133	0.839	30.4	23.4	0.513	2.46	0.00315	208,000	15.0
347	5.60	6.23	0.568	2.32	1.32	42.6	0.0923	0.836	43.9	33.8	0.423	2.31	0.00133	226,000	17.7
486	5.17	5.82	0.538	2.17	1.16	42.6	0.0665	0.836	61.0	46.9	0.337	2.16	0.00109	238,000	19.6
660	4.80	5.47	0.508	2.04	1.04	42.6	0.0412	0.836	98.3	75.7	0.268	2.03	0.00074	269,000	23.0
965	4.48	5.17	0.479	1.93	0.925	42.6	0.0293	0.836	138	106.2	0.210	1.92	0.000365	284,000	27.9
1146	4.20	4.90	0.452	1.83	0.823	42.6	0.0198×10^4	0.836	204	157.5	0.168	1.83	0.000555	308,000	32.9
1692	3.74	4.47	0.398	1.66	0.663	42.6	9.42×10^{-5}	0.836	430	331	0.1045	1.66	0.000293	332,000	43.0
2730	3.32	4.08	0.340	1.52	0.521	42.6	4.17×10^{-5}	0.835	972×10^{11}	748×10^{11}	0.0597	1.52	0.000140	400,000	55.5

* Corrected for blank run cell compression using Figure 6

† Corrected for medium and cell resistance using blank run data for R_m (Fig. 6)‡ Effective value calculated from K-C relationship assuming $K = 5$ ** Effective value calculated from K-C relationship assuming $S_s = 120,000$ sq.cm./cu.cm. solid as before consolidationCake contained 7.1633g. dry solids, or $\frac{7.1633}{2.67} = 2.685$ cu.cm. dry solids

$$R = \frac{A g_p \Delta H}{Q} = \frac{(11.35)(32.2)(1.00)(30.45)^2}{(\text{cu.cm./sec./cm. Hd.}) \times \mu (1 + \epsilon_p)} = \frac{3.39(10)^5}{(\text{cu.cm./sec./cm. Hd.}) \times \mu (1 + \epsilon_p)}$$

$$R = \left(\frac{a_p W}{A} + R_m \right)$$

$$a_p = (R - R_m) \frac{A}{W} = (R - R_m) \left(\frac{454}{(30.45)^2} \right) \left(\frac{11.35}{7.163} \right) = 0.77(R - R_m) = \text{ft./lb.}$$

$$S_s^2 = \frac{p_s}{K} (0.0672) a_p \left(\frac{\epsilon^2}{1 - \epsilon} \right) = \frac{\text{cm.}^4}{\text{cm.}^2}$$

$$S_s^2 = \frac{2.67}{5} (0.0672) a_p \left(\frac{\epsilon^2}{1 - \epsilon} \right) = 0.0359 a_p \left(\frac{\epsilon^2}{1 - \epsilon} \right)$$

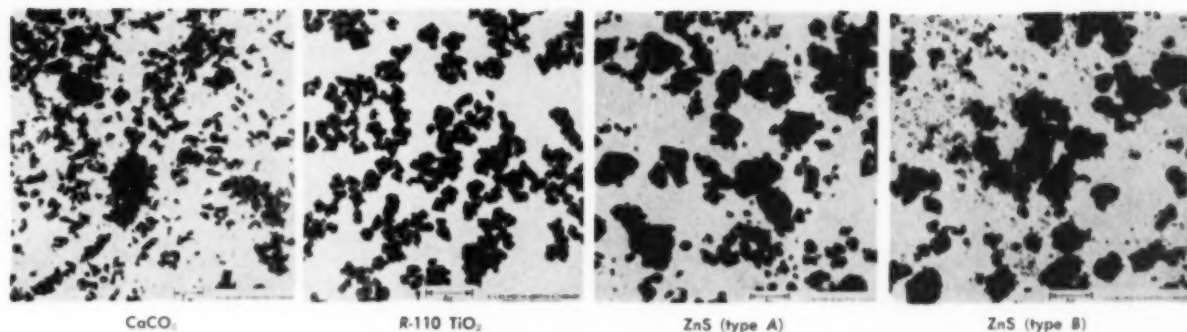


Fig. 5. Electronmicrographs of materials tested.

Results with the spherical carbonyl iron powders show a very weak initial flocculation which broke down under very low p_a to yield a cake with nearly constant α_p and ϵ_p over a wide p_a range, the values of ϵ_p being in the range expected for normal packing of spherical particles. The change in effective S_o with these spherical particles was small over a wide range of p_a values and agrees within 10 to 20% with the S_o values determined from micrographs, size-distribution data, and nitrogen-adsorption measurements.

The high degree of initial flocculation existing with the spherical particles of Dow polystyrene latex resulted in an initial cake of very high porosity ($\epsilon_p = 0.95$). The cake consolidated rapidly under increasing p_a , giving a rapidly rising α_p function and rapidly decreasing ϵ_p function, which tended to level out above 10 to 100 lb./sq.in. compressive pressure in the normal range of ϵ_p expected for spherical particles. The effective S_o of the cake with these flocculated latex spheres remained constant for a short period of compression, representing consolidation of cake by shifting of flocs; rose rapidly for a considerable range during a period of cake consolidation resulting from floc breakdown; and leveled out over a region representing complete floc breakdown and consolidation by rearrangement of ultimate particles only. The constant effective S_o value over this latter range was only 20% above that determined from the micrographs.

Suspensions of the irregular tungsten and talc were highly flocculated and formed a flocculated cake structure which broke down slowly under increasing compressive pressure. The irregularity of the particles with these materials promoted flocculation and a strong flocculated cake structure, because of the greater surface contact and interlocking possible in the flocs. At low compressive pressure, α_p increased and ϵ_p decreased steadily with increasing p_a ; however, at higher p_a values the variation in α_p and ϵ_p became more rapid as floc breakdown became more rapid. For

these materials the effective S_o increased steadily with increasing p_a and decreasing ϵ_p , indicating the complete failure of the Kozeny-Carman relationship as expressed in Equation (6) unless an actual change in effective S_o is assumed to occur during consolidation.

Correlation of the physical compressibility of the cakes, as is demonstrated in plot *c* of Figure 8, results in a straight line with most materials, although some, such as the Dow polystyrene latex, exhibit a single point of inflection. Although the absolute value of physical compressibility at a given p_a value varied widely for different materials, the compressibility gradient or slope of these physical compressibility curves did not vary greatly for most materials examined. The scatter in these curves of physical compressibility results largely from the plotting of original data directly in incremental form.

Figure 5 shows photomicrographs of three irregular-shaped particulate materials which were each studied for two different degrees of feed-suspension flocculation. The ultimate particles of calcium carbonate were of irregular shape in the size range of 0.2 to 1.0 μ and had a surface average diameter of 0.37 μ as determined from nitrogen-adsorption measurements. The ultimate particles of titanium dioxide were irregular in shape but relatively uniform in size, having a surface average diameter of 0.18 μ , as determined from nitrogen-adsorption measurements. The micrographs of the suspensions of zinc sulfide precipitated by different procedures show suspension A to be more highly flocculated than suspension B, with the ultimate particles probably under 0.1 μ in size.

Figure 9 shows the results of compression-permeability study of these materials in the same manner as Figure 8. At low values of p_a , the more highly flocculated suspension of each material results in a cake with a fivefold to tenfold lower α_p , and a higher ϵ_p , than does the more dispersed suspension. Both α_p and ϵ_p of the cake deposited from the flocculated suspensions are much more

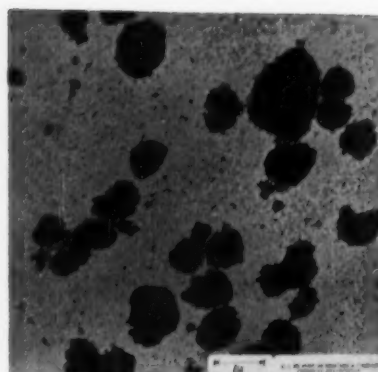
pressure dependent than the α_p and ϵ_p values for cakes deposited from the more dispersed suspension.

For the titanium dioxide of relatively uniform ultimate particle size, the effective S_o values for cakes from both the flocculated and the dispersed suspensions leveled out on consolidation to a value in general agreement with values indicated by micrographs and determined from nitrogen adsorption. With the dispersed suspension a nearly constant effective S_o resulted, indicating good initial dispersion and little floc breakdown on consolidation. With the flocculated titanium dioxide, the effective S_o increased only 20% before leveling out, indicating rather rapid floc breakdown where irregular particles were all of nearly equal size and very similar in shape.

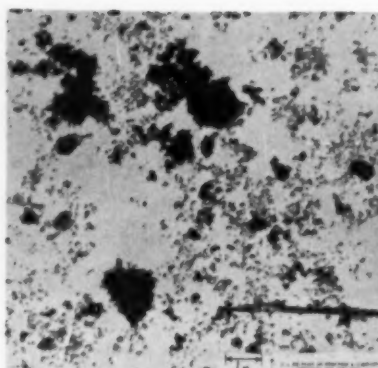
The highly flocculated suspension of calcium carbonate shows a continual increase in effective S_o over the entire consolidation range considered, while the less flocculated suspensions produce a cake which showed an initial increase in effective S_o but which exhibits a leveling out of effective S_o at a value in close agreement with that obtained by nitrogen-adsorption measurements. The dissimilar particle shapes present in this material probably promote a strong flocculated structure and make complete dispersion more difficult.

The large difference in the values of α_p for the differently treated suspensions of zinc sulfide and the high degree of compressibility of cakes from both suspensions is well shown by these measurements. These materials were highly flocculated as evidenced by the rapid increase in effective S_o of each over the entire consolidation range covered. Although both were highly flocculated, an eight- to ten-fold difference in cake resistance existed between these materials, emphasizing the large effect of even small changes in degree of flocculation.

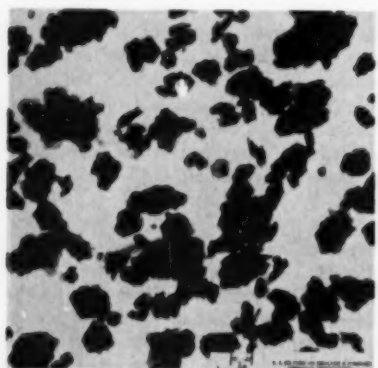
Figure 6 shows micrographs of four additional irregular materials studied, including three plant materials of small ultimate-particle size. The kaolin was made up of irregular size and shapes of



Fine silica



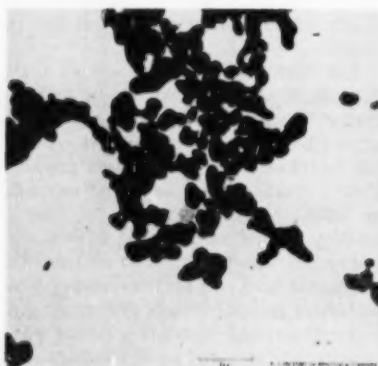
G-60 Darco



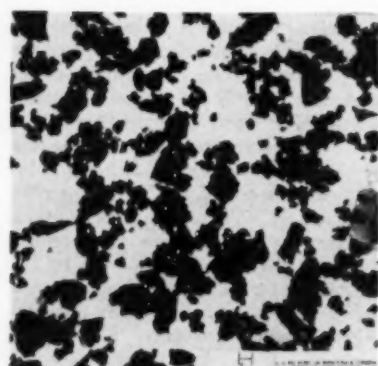
Kaolin



Iron blue pigment



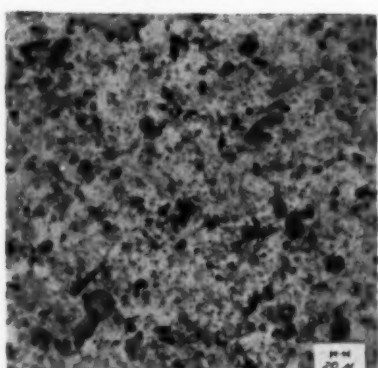
Linde alumina



Fine ilmenite



BW-200 Solka-Floc



Standard Super-Cel

Fig. 6 and 7. Electron- and photomicrographs of materials tested.

thin plates, 0.25 to 2 μ in diameter, and the surface average diameter from nitrogen-adsorption measurements was 0.35 μ . The G-60 Darco, fine silica, and iron blue pigment were made up of irregularly shaped particles of 0.1 μ or smaller size, but highly flocculated as normally handled. The particles of iron blue pigment appeared to be quite uniform in size and shape compared to those of G-60 Darco and fine silica.

Figure 10 shows the results of compression-permeability study of cakes of these materials. The important effect of initial-suspension flocculation is again apparent from the results with the two differently flocculated kaolin suspensions. The effective S_o of cakes from both these suspensions approaches a constant value at low ϵ_p , which agrees within 20% with the value measured by nitrogen adsorption.

Results with cakes of the three very fine materials emphasize the high cake porosities which can be expected to result with cakes deposited from the highly flocculated suspension of such materials. A high initial porosity (0.85 to 0.98) and a relatively low α_p are characteristic of these cakes, as are a rapid decrease in ϵ_p and increase in α_p with increasing p_c and cake consolidation. A rapid increase in effective S_o as consolidation proceeds is characteristic of these materials and is representative of the gradual collapse of the flocculated structure to form a more uniform packing of the ultimate particles. With the relatively uniform-size and -shape particles of iron blue pigment, the degree of flocculation was not so great as with more irregular silica and Darco, resulting in the effective S_o leveling out to a constant value as consolidation proceeded. Near the end of the consolidation range covered, the effective S_o values for fine silica and G-60 Darco also started to show evidence of a leveling out of effective S_o values.

Figure 7 shows micrographs of four additional materials studied, including a diatomaceous earth and a fibrous filter aid. The Standard Super-Cel is of extremely irregular and random particle shape and covers a wide particle-size range; the surface average diameter from nitrogen-adsorption measurements was 0.52 μ . The BW-200 Solka-Floc was fibrous and was the only material examined which was composed of deformable particles; the surface average diameter from nitrogen-adsorption measurements was 4.8 μ . The TFE-4 fine ilmenite was of moderately irregular particles of 0.25 to 5 μ size with a surface average diameter of 0.37 μ as determined from nitrogen-adsorption measurements. The Linde type A alumina was of relatively uniform-size particles, 0.25 to 0.5 μ , of thin platelike structure,

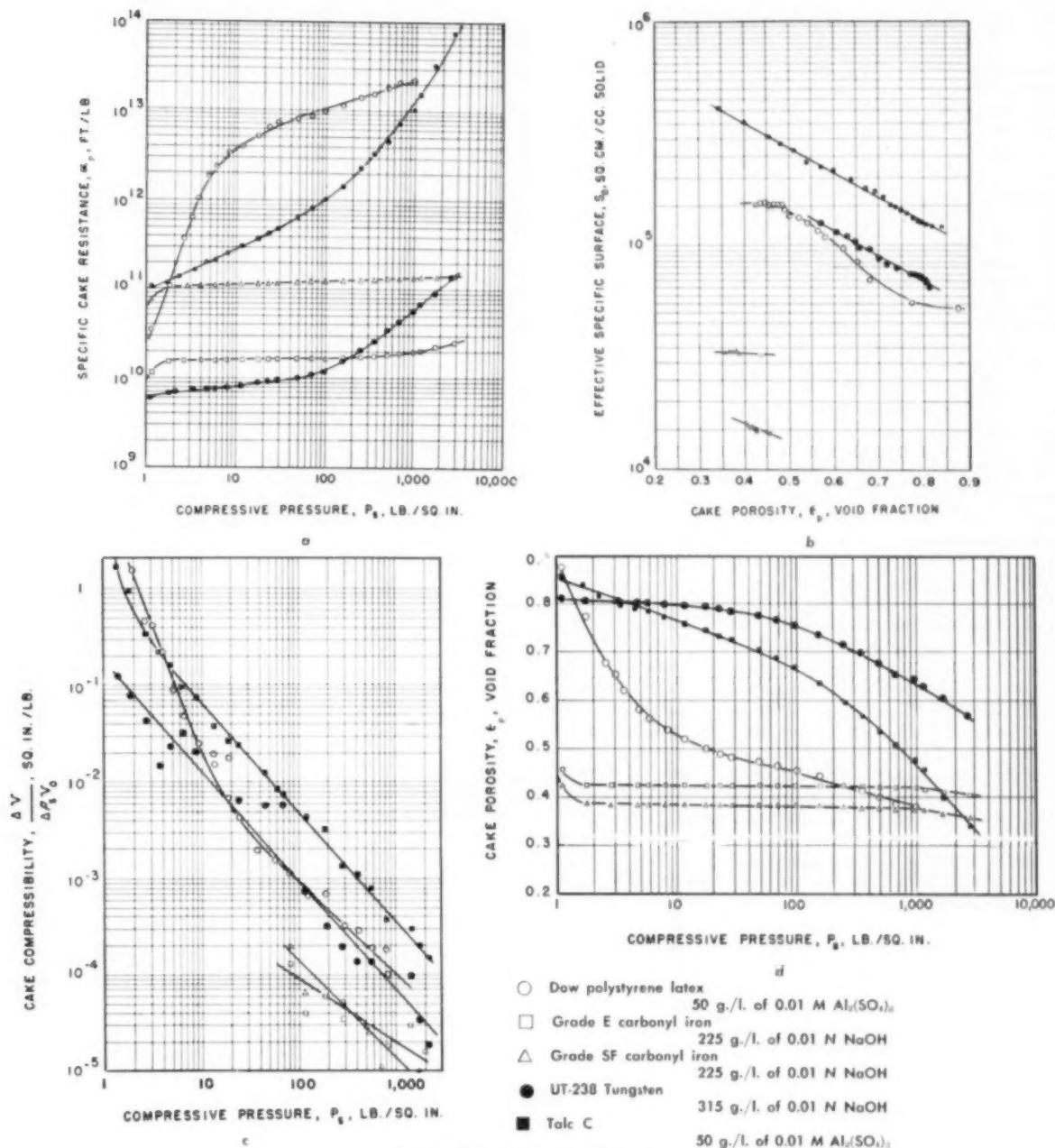


Fig. 8. Compression-permeability data.

with a surface average diameter of 0.24μ as determined from nitrogen-adsorption measurements.

Figure 11 shows the results of compression-permeability study of filter cakes of these materials. The extreme irregularity and randomness of particle shape and wide particle-size distribution in the Standard Super-Cel do not appear to be a major factor affecting dependence of a_p and p_s , since variation of a_p with p_s is much less for the Standard Super-Cel than for the highly flocculated, but relatively uniform in ultimate size and shape, particles of

Linde Type A alumina. The BW-200 Solka-Floc shows a much greater variation of a_p with p_s than was encountered for any other materials examined; this probably results from the deformable nature of these fibrous particles. A much greater change in effective S_0 with consolidation of the cake was also characteristic of this material. Here the increase in effective S_0 of the bed probably represents collapse of cake structure because of fiber deformation as well as floc breakdown. The much greater changes accompanying particle deformation or crushing indicates that this

effect was not a major factor in measurements made on the other materials.

CAKE RESISTANCE

In general, the curves of a_p vs. p_s vary considerably in form for the seventeen materials examined and do not lend themselves to direct mathematical treatment. The values of a_p were calculated directly from Equation (1), as indicated in Table 1. Early examination of the dead-void volume hypothesis proposed by Ruth (49) showed that it was based on the assumption of a simplified por-

osity function and excessive extrapolation of original data plotted as (flow rate/liquid head)^{1/2} vs. specific void volume. These data, which cover a much wider range of compressive pressure, show that such a plot in reality is not a straight line at high compressive pressures but is a curve which passes through the origin. Plots of original data in the form of (flow rate/liquid head) vs. $\epsilon^3/1-\epsilon$, which is the established porosity relationship of Equation (6), resulted in smooth curves over the entire porosity range, and these curves passed through the origin, indicating no so-called dead-void volume.

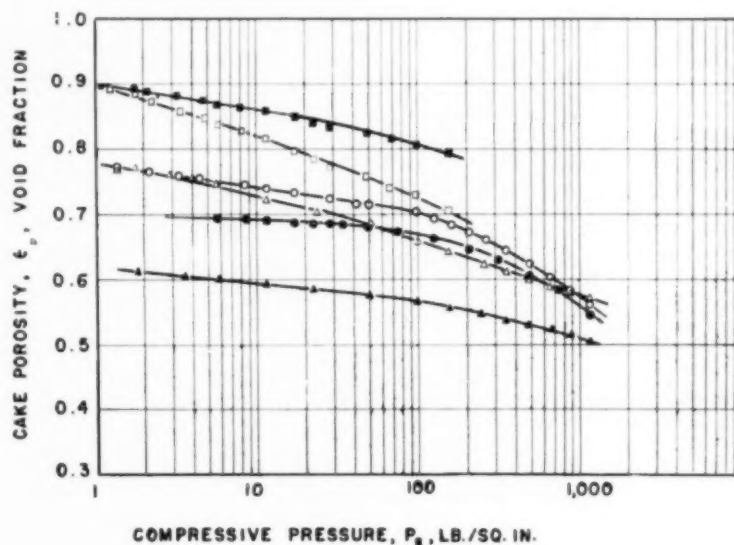
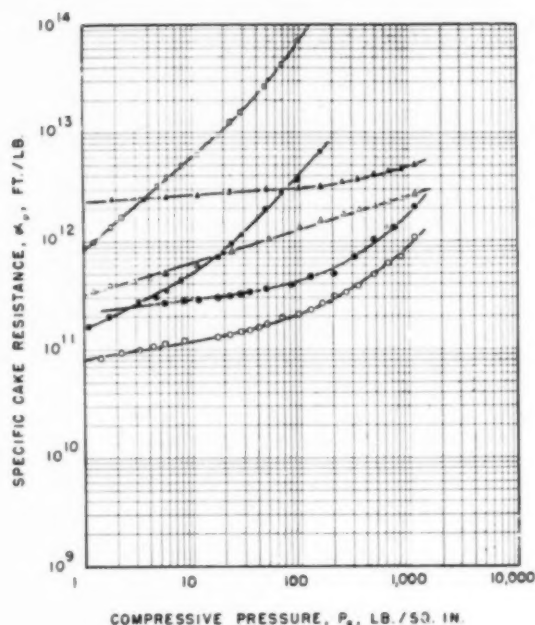
With many of the materials, semilog plots of α_p vs. ϵ_p resulted in a straight line over a considerable range of porosity, plot 1 of Figure 12 indicating a relationship of the form $\alpha_p = e^{-B'\epsilon_p}$. This is in contrast to the exponential relationship Durwez and Green (24) found between their viscous resistance coefficient and porosity for consolidated porous media. The porosity range over which this semilog relationship was found to hold corresponds to that over which a similar relationship holds for plots of S_o vs. ϵ_p (Fig. 8 to 11). The values of α_p and the form of the α_p vs. p_c curves for a given material varied widely, depending on degree of flocculation existing in the prefilter with various electrolytes present. That this wide variation in α_p represented actual changes in particle flocculation was confirmed by microscopic examination and light-extinction measurements on prefilter suspensions, as will be discussed in Part II of this paper. The hypothesis of Ruth (49) that a back electrosmosis or electroviscous effect might account for these same effects was considered in the light of recent theoretical work by Booth (8) and Elton (26). However, calculations based on the formulas that they developed for predicting the magnitude of this effect show that at the electrolyte concentration employed, the effect would be negligible even if a back electrosmosis or electroviscous effect exists. Experimental verification of this effect is still lacking; moreover, recent experimental work by Dobry (22) has indicated that this postulated effect cannot be realized in practice.

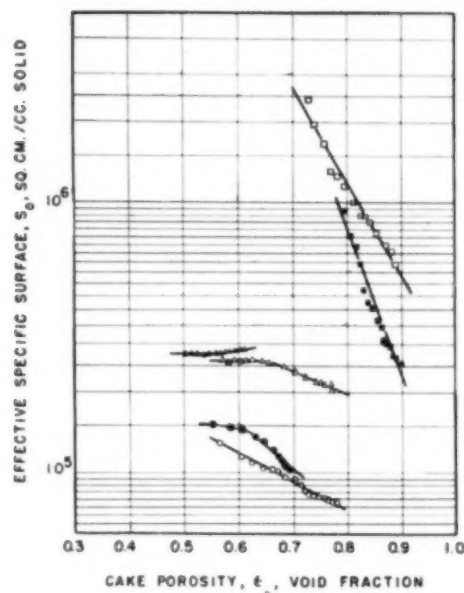
PHYSICAL COMPRESSION OF CAKE

Data of Spencer (51) on the consolidation of dry granular polymers under very large compressive pressures show $\epsilon = \epsilon_0 e^{-\gamma p_c}$ to describe satisfactorily the average porosity variation with compressive pressure at compressive pressures above 2,000 lb./sq.in., but correlation below this compressive pressure was poor. Other such correlations by Lecuir (37), Durwez and Zwell (25),

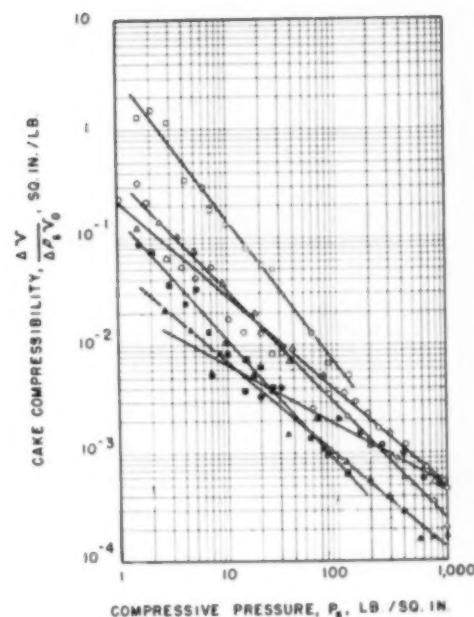
and Lipson (38) are also applicable only to very high compressive pressures as used in powder metallurgy, and they deal in general with the case of non-uniform porosity distribution existing in dry powder compacts of length-to-diameter ratio greater than unity under very large compressive pressures. These references report, however, that the addition of a small amount of a liquid to the compact greatly increases uniformity of compact through a lubricating action. This bears out the results of this work, which show that, with liquid-saturated cakes of thickness-to-diameter ratio less than 0.6, essentially uniform porosity

distribution exists in the range of compressive pressures (1 to 2700 lb./sq.in.) as used in this study. The very fine particles in the filter cakes probably result in an entirely different behavior from that encountered in compaction of plastic and metal powders, where very fine particles are avoided. As discussed by Crone (20), the role of fine particles in determining the initial cake structure and manner of any subsequent consolidation is probably controlling through the development of an initial structure of large flocs and large voids. The strength of this flocculated structure depends on (a) the surface-to-volume





b



c

- Superlight CaCO_3 (floculated)
50 g./l. of distilled water pH = 9.8
- Superlight CaCO_3
50 g./l. of 0.01 M $\text{Na}_2\text{P}_2\text{O}_7$ pH = 10.3
- △ R-110 grade TiO_2 (floculated)
50 g./l. of distilled water, pH = 7.8
- ▲ R-110 grade TiO_2
50 g./l. of 0.01 N HCl pH = 3.45
- ZnS
Type 8 pH = 9.07
- ZnS
Type A pH = 9.10

Fig. 9 (a to d). Compression-permeability data.

ratio of the ultimate particles, (b) the contact area between particles per unit volume of ultimate particle, (c) mechanical interlocking of particles packed together to form flocs, and (d) strength of surface forces causing adhesion of particles within the floc. Assuming (d) remains constant per unit area of contact, anything causing an increase in (a to c) would increase strength of flocculated structure. Irregularity of particle shape is the single factor which will increase (a to c) and it, therefore, should promote strength in the flocculated cake structure. This was borne out by compression-permeability results on spherical and irregular materials. Flocculation was difficult to obtain with the spherical particles, and the resulting flocculated cake structure broke down rapidly at low p_c values. With irregular materials, flocculation was difficult to prevent and resulted in a cake structure which broke down slowly over a wide p_c range.

Data on the seventeen materials examined by compression-permeability measurements show previously developed relationships (51, 37, 25, and 38)

for ϵ_p variation with p_c to fail badly below 1000 lb./sq.in., which was the main region of interest in this work. The logarithmic plots of physical compressibility, $\Delta V/V_0 \Delta p_c$ vs. p_c of Figures 8 to 11, give a single straightline correlation for each material over the total p_c range from 1 to 2700 lb./sq.in., with fourteen of the seventeen materials used. Three of the materials showed a single inflection point, indicating a change in consolidation mechanism. The scatter of points on these plots results largely from calculations based on increments between actual data points rather than on increments between points on a smoothed curve. Since the physical compressibility can also be written as $\Delta(1/(1-\epsilon_p))/\Delta p_c$, the plots of Figures 8 to 11 yield the relationship $d(1/(1-\epsilon_p))/dp_c = a p_c^\gamma$. Integration, for $\gamma \neq -1$, results in a final porosity-pressure function,

$$\frac{1}{1-\epsilon_p} - \frac{1}{1-\epsilon_0} = \frac{a p_c^{\gamma+1}}{\gamma+1} \quad (7)$$

where a and γ are both negative and can be determined from Figures 8 to 11, while ϵ_0 can be calculated by substitution. For values of $\gamma > -1$, the value of ϵ_0 is less than 1.0 and may have physical significance. For values of $\gamma < -1$, the value of ϵ_0 is greater than 1.0, and the relationship probably fails at some very small value of p_c .

With titanium dioxide and calcium carbonate, which were both studied as deposited from preflit exhibiting different degrees of particle flocculation, material deposited from the more highly flocculated preflit resulted in a cake

of higher initial ϵ_p and lower initial a_p than did the same material deposited from the less flocculated preflit. In a similar manner the more flocculated material exhibited a greater physical compressibility as well as a more rapid increase in a_p with increasing p_c , emphasizing the role of particle flocculation in determining the physical structure and properties of the resulting cake.

KOZENY-CARMAN RELATIONSHIP

All the seventeen materials examined, with the exception of the spherical carbonyl iron powders, showed an appreciable change in effective S_e calculated from Equation (6), as cake consolidation proceeded and ϵ_p decreased (shown in plot b of Figures 8 to 11). With many of the fine materials, where a high degree of flocculation existed, this increase was a hundredfold or greater in magnitude. This increase in effective S_e with decreasing porosity can be satisfactorily described by $S_e = S_e^0 e^{-\beta \epsilon_p}$ over a considerable consolidation range, as shown by the straightline plots of Figures 8 to 11. The curves for several materials leveled out at low porosity values, indicating that floc breakdown was complete and Equation (3) was satisfied by a constant S_e value. A few showed a brief period of nearly constant effective S_e at very high porosities, which was probably representative of a period of cake consolidation by rearrangement of floc packing without floc breakdown. Over most of the range of interest, however, application of Equation (3), assuming $K = 5 \pm 10\%$ as established for random-packed beds of

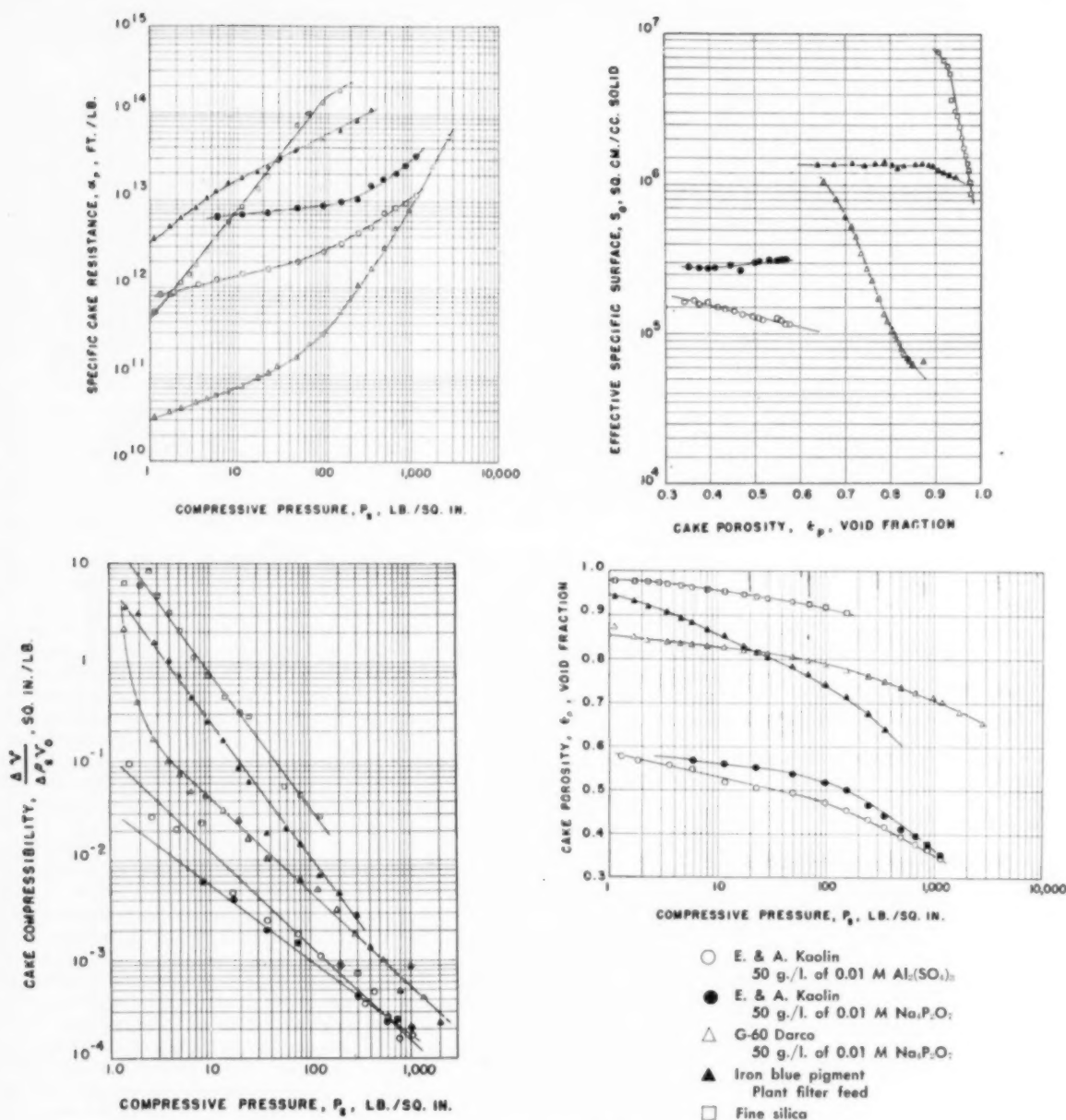


Fig. 10. Compression-permeability data.

larger particles of varying shape, resulted in a changing effective S_0 . Thus, unless the view is accepted that the effective S_0 influencing flow through most filter cakes changes during consolidation and is dependent on conditions of pressure stress existing in the cake, it must be concluded that the Kozeny-Carman relationship is not satisfactory as applied to the compressible filter cakes studied.

The reason for the apparent failure of the established relationship in this case is the changing quality of voids which accompanies increasing pressure stress with compressible cakes. In de-

riving the Kozeny-Carman relationship, Kozeny made and Carman accepted several assumptions that are not valid for the case of compressible filter cakes. Carman (14) has clearly stated these limiting assumptions. The derived relationship assumes that no pores are sealed off and that all voidage is available to fluid flow; this may be open to question with compressible filter cakes, where actual physical compression with increasing pressure stress may halve the cake thickness. On the other hand, recent work by Warren and Libsch (56) on pressing metal-powder compacts shows that 100% of pore volume is

available to flow even after pressing at 75 tons/sq.in. pressure. More serious is the assumption that the pores are and remain reasonably uniform in size and shape throughout the bed as consolidation proceeds. This implies that particle agglomeration or flocculation is not a factor. Cakes formed of particle agglomerates result in a bed containing relatively large voids between agglomerates and small pores within the agglomerates (small and large pores in parallel). As the pressure is increased, the initial effect is for the agglomerate to deform or break down with reduction of the large voids between agglomerates

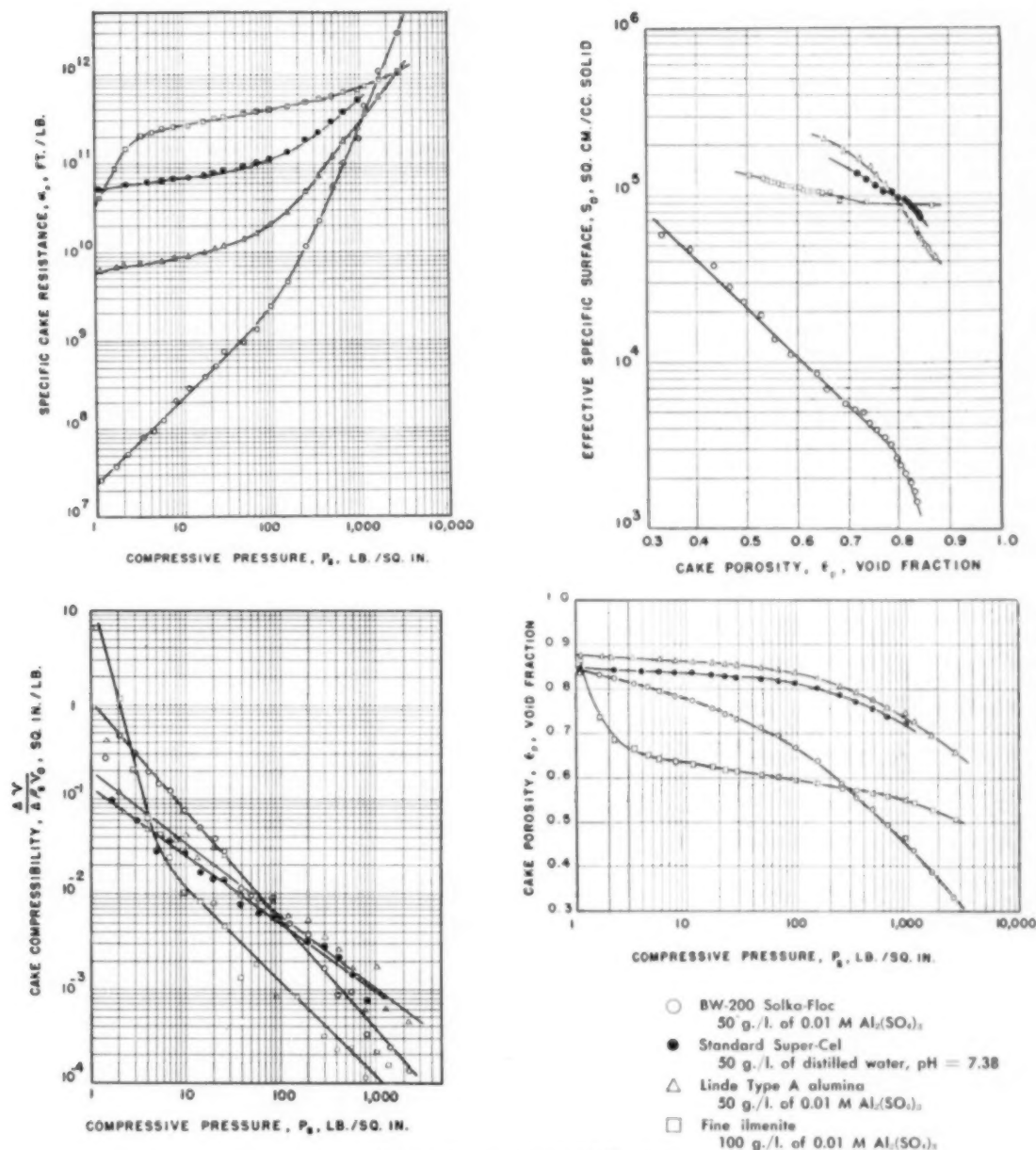


Fig. 11. Compression-permeability data.

and a tendency toward a more uniform packing and voidage distribution. Thus particle flocculation during cake formation (small and large pores in parallel) results in too low a calculated specific surface at low pressure stresses (high porosity) and causes the calculated particle specific surface to increase toward the actual value for the discrete particles as pressure stress is increased and floc breakdown or deformation proceeds. This is the effect noted with many of the materials studied.

Conversely, however, with a wide particle-size distribution and particle segregation during cake formation (small and large pores in series), the

calculated specific surface at low-pressure stress (high porosity) will be too high; but, as the pressure stress is increased, the cake will tend toward a more uniform packing, and the calculated particle specific surface will decrease toward the actual value for the discrete particles. This effect was obtained with a very low permeability cake of kaolin deposited from a dispersed suspension, the time of deposition being so long that considerable sedimentation occurred, giving particle segregation within the cake.

This difficulty of an increase in effective S_0 with decreasing ϵ_p has been reported recently by Carman and Arnell

(16), Carman and Malherbe (17), Childs and Collis-George (18), Robertson and Mason (46), and Dalla Valle (21), working in the field of specific surface measurement of fine dry powders and fibers by permeability methods. For very fine-particled materials the effect is undoubtedly caused by particle flocculation. This results in a nonuniform pore distribution with large and small pores in parallel before consolidation and an effective specific surface, calculated from permeability measurements, which is less than that for ultimate particles, as discussed above. For the fibrous materials, the effect is probably caused by nonuniform pore distri-

bution resulting from fiber deformation and changing pore shape as well as from flocculation. On the other hand, recent work by Martin (41) on the effect of voidage shape with various packings of spheres has shown that the Kozeny-Carman relationship gives at least the correct order of magnitude for a wide range of pore shapes resulting from prepared geometrical packings of discrete spheres of large size.

The alternates to acceptance of variation of effective S_0 of filter-cake materials as consolidation occurs are (a) empirical correction of the porosity function of Equation (6) to satisfy conditions of a constant S_0 , or (b) assumption that K is not a constant but increases during consolidation, thus accounting for the increase in effective S_0 calculated assuming K is constant. The upper plot of Figure 12 shows α_p vs. ϵ_p determined by compression-permeability measurements on several of the materials examined. It also shows the predicted variation of α_p with ϵ_p according to Equation (3), assuming S_0 remained constant as initially determined for each material and $K = 5$. Thus, the slope of all predicted curves is the same and representative of the porosity function $(1 - \epsilon_p)/\epsilon_p^3$ as contained in Equation (6). The slopes of the actual curves could be used to establish an empirical porosity function of the form $e^{-\beta'\epsilon_p}$. However, there is little evidence in favor of this since the values of β' appear to be different for each material. Other porosity functions have been adopted by Keyes (34), Arnell (3), Furnas (30), and Brownell (10), but they vary with effective particle shape and, therefore, also necessitate experimental determination with each filter-cake material where flocculation is a factor.

On the other hand, if the existing porosity function is correct and S_0 remains constant, then K must increase with consolidation as a result of change in shape of void passages and an increase in the length-of-flow-path-to-bed-thickness ratio as consolidation occurs. Coulson (19) has recently shown that K may vary from 3 to 15 with different orientations of platelike materials and also may increase considerably as consolidation occurs with beds of platelike particles. Recent work on permeability of fibrous beds by Anderson and Warburton (2) and by Brown (9) has confirmed earlier work by Sullivan and Hertel (55) which showed that K changes with packing orientation and could be expected to change on consolidation. Adamson (1) and Wyllie and Rose (57) have recently reported that very large values of K have been determined for consolidated porous media, employing an independent method of

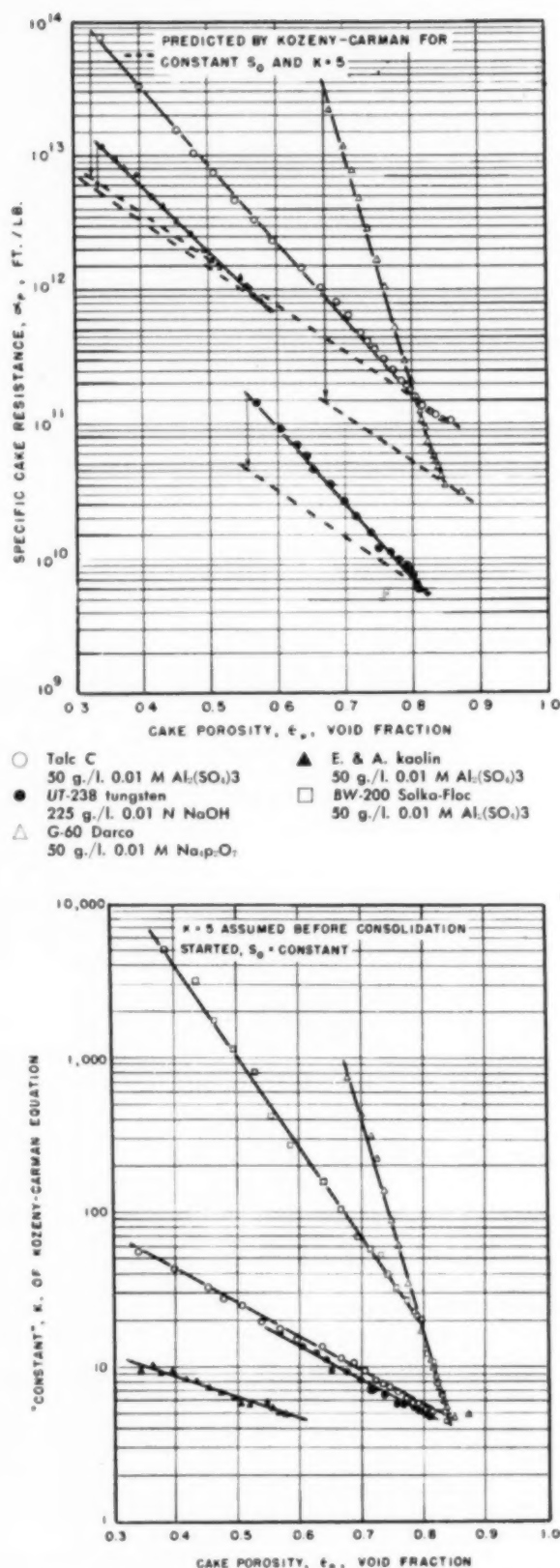


Fig. 12. Empirical correction methods for Kozeny-Carman equation for specific materials.

measurement, and that an increase in K occurs on consolidation. A drag theory for permeability of porous fiber beds recently proposed by Ilerall (33) also predicts an increase in K as consolidation occurs. The lower plot of Figure 12 shows the variation of K occurring with several of the materials studied, assuming that the porosity function of Equation (6) is correct and that $K = 5$ before consolidation was started. The resultant increase in K is a hundredfold or greater in several cases, while that indicated by most of the recent references cited above is only two to twentyfold. On the basis of this cited work and also on the theoretical basis, such a large increase in K alone is difficult to justify. The variation of K may be expressed as a simple function of ϵ_p over a considerable consolidation range. It is significant, however, that the effective S_o value calculated for many of the cakes studied, assuming $K = 5$, is very near the S_o value measured by nitrogen adsorption, provided the bed porosity is reduced to a voidage range of 0.4 to 0.5 (Table 1). This is the normal porosity range for random packing of a wide range of irregular materials too large to be affected by flocculation and is the porosity range for which $K = 5 \pm 10\%$ was established for random packing. This indicates that $K = 5$ may actually be true when consolidation of the bed has proceeded to a point where floc breakdown is complete and a random packing of the ultimate particles is achieved. This viewpoint agrees with that of Carman and Malherbe (17), who strongly advocate measurement of S_o at "normal porosities," i.e., in the range of $\epsilon = 0.4$ to 0.5.

The most tenable position at this time appears to be that both K and the effective S_o vary with many of the materials studied. The change in K with consolidation is probably relatively small, possibly a 25 to 100% increase at most, while the change in effective S_o resulting from floc breakdown during consolidation accounts for the larger variation with the highly flocculated materials. Thus, use of the Kozeny-Carman relationship with independently determined values of particle size or specific surface gives a highly inaccurate value of specific cake resistance with most filter cakes because of the unknown degree of particle flocculation existing before cake formation. Conversely, effective specific surface determined from permeability measurements on a deposited filter cake is dependent on the degree of flocculation existing before cake deposition and on compressive pressure existing (degree of consolidation achieved) at the time of measurement. As a result, compression-permeability measurements on a single cake, or a series of actual con-

stant-pressure filtration experiments, remain necessary for establishment of cake properties and filtration rates with each different suspension, even when ultimate particle size and shape are known.

Summary

The compression-permeability method has been found to be a rapid and practical method for determining the properties of compressible filter cakes. This new method results in measurement of specific cake resistance, cake porosity, and effective specific surface of cake solids over a wide range of compressive pressure, thereby permitting complete definition of the filtration characteristics of a given suspension by study of a single cake. Application of this technique to cakes of seventeen materials has shown:

1. The compressible nature of most industrial filter cakes (i.e., the resultant increase in cake resistance with increasing filtration pressure drop) results largely from particle flocculation in feed suspension. The greater the degree of particle flocculation with a given material, the lower is the specific cake resistance, but the more compressible is the cake.

2. Ultimate particle size and size distribution have very little direct effect on the over-all compressibility of most filter cakes. Indirectly, particle size has a large effect, however, by promoting flocculation as the size becomes smaller and surface-to-volume ratio becomes larger.

3. Particle shape has little direct effect on over-all cake compressibility, but can have a very large indirect effect by greatly promoting flocculation. Thus, whereas flocculation may not become important under most conditions with spherical particles until the particle diameter becomes less than 1 to 2μ , with very irregular materials flocculation can be an important factor under most conditions even with particles having one or two dimensions as large as 20μ . In this respect the surface average diameter is a better criterion of flocculation effects than other particle-size information.

4. The physical consolidation of filter cakes under increasing compressive pressure can be correlated satisfactorily for most materials over the pressure-stress range likely to be encountered in filtration and mechanical-expression operations, permitting prediction of results from a minimum of data.

5. The Kozeny-Carman relationship cannot be employed in the usual manner when applied to filtration of compressible filter cakes. For this important case, the effective specific surface of solids in the resulting cake depends on

both the degree of flocculation in the feed suspension and the pressure stress existing under filtration conditions. Thus independently measured values of particle size or specific surface cannot be used to calculate filtration performance unless they are measured on cakes deposited from the actual feed suspension and the compressive pressure existing throughout the actual filter cake is taken into account. Application of the compression-permeability method will supply these basic data necessary to calculation of filtration performance under any condition of filtration pressure drop.

6. Empirical correction of Kozeny-Carman relationship, as applied to compressible cakes, can be made for a given cake on the basis of compression-permeability measurements, but no general correction or modification appears possible where particle flocculation is a factor.

Acknowledgment

Electronmicrographs contained in this paper were made by Carl E. Wiloughby and R. F. Fisher of the chemical department, E. I. du Pont de Nemours and Co. The specific surface measurements by nitrogen adsorption were made by Charles G. Wortz, also of the chemical department.

Notation

- a = constant in equation for physical compressibility, sq.ft./lb.
- A = cross-sectional area of cake perpendicular to direction of flow, area of active filter medium, sq.ft.
- d = differential operator
- D_s = specific surface average diameter, μ
- g_c = conversion factor in Newton's law of motion, 32.2 (lb.)(ft.)/(lb. force) (sec.)²
- K = constant of Kozeny-Carman equation ($\approx 5 \pm 10\%$ for random packing of discrete particles) = $k_s(L_s/L)^2$
- k_s = constant, a function of particle shape and orientation in packed bed
- L = cake thickness in direction of flow, ft.
- L_c = length of actual flow path through cake, ft.
- p = hydraulic pressure at a point in cake, lb./sq.ft. of cake cross section
- p_d = hydraulic pressure on discharge side of filter medium, lb./sq.ft.
- p_f = hydraulic pressure on cake side of filter medium, lb./sq.ft.
- p_e = hydraulic pressure at exposed surface of filter cake, lb./sq.ft.
- p_t = total mechanical compressive pressure developed in cake structure in direction of flow, lb./sq.ft. of cake cross section
- Δp = total hydraulic-pressure drop across cake and filter medium in pressure filtration, lb./sq.ft.

Δp_c = hydraulic-pressure drop across cake in pressure filtration, lb./sq.ft.
 Q = instantaneous rate of filtrate flow through cake, cu.ft./sec.
 R_m = filter-medium resistance, 1/ft.
 s = compressibility factor of filter cake, $s = a_0 + a'(p_2 - p_1)^s$, dimensionless
 S_0 = particle specific surface, sq.ft./cu.ft. solid^a
 u = superficial flow velocity through cake, ft./sec.
 V = volume of filtrate collected at time, θ
 v = actual cake volume, cu.ft.
 v_0 = volume of solid particles in cake, cu.ft.
 W = total weight of solid particles in cake, lb.
 w = weight of solid particles deposited in cake per unit volume of filtrate, lb./cu.ft.
 a = average specific cake resistance of actual filter cake (weight basis), ft./lb.
 a_p = specific cake resistance at any point in cake, ft./lb.
 a_0 & a' = constants of equation $a = a_0 + a'(p_2 - p_1)^s$
 β, β' = coefficients in possible empirical methods of correcting Kozeny-Carman relationships when applied to cakes of flocculated particles
 β'' = constant in empirical equation $a_p = a - \beta'' \epsilon_p$
 γ = physical compressibility coefficient
 ϵ = average cake porosity or void fraction, dimensionless
 ϵ_p = porosity, or void fraction, at any point in cake, dimensionless
 θ = time of filtration, sec.
 ρ_f = density of suspending liquid or filtrate, lb./cu.ft.
 ρ_s = density of solid particles, lb./cu.ft.
 μ = filtrate viscosity, lb./ft.sec.
 $N_{Re} = \rho_f u / \mu S_0 (1 - \epsilon_p)$, Reynolds number, dimensionless

Consistent units, suitable for direct use in all equations of this paper, are given in this notation. More readily grasped units have been used in plotting several of the curves shown in the figures.

Literature Cited

- Adamson, J. E., *Nature*, **166**, 314 (1950).
- Anderson, S. L., and F. L. Warburton, *J. Textile Inst.*, **40**, T749 (1949).
- Arnell, J. C., *Can. J. Research*, **A24**, 103 (1946).
- Arnell, J. C., *Can. J. Research*, **A27**, 207 (1949).
- Blaine, R. L., *A.S.T.M. Bull.*, **108**, 17 (1941).
- Bloomfield, A. L., *Trans. Inst. Chem. Engrs. (London)*, **3**, 38 (1928).
- Bonilla, C. F., *Trans. Am. Inst. Chem. Engrs.*, **34**, 243 (1938).
- Booth, F., *Proc. Roy. Soc. (London)*, **203A**, 533 (1950).
- Brown, J. C., *TAPPI*, **33**, 130 (1950).
- Brownell, L. E., and others, *Chem. Eng. Progress*, **46**, 415 (1950).
- Carman, P. C., *J. Soc. Chem. Ind.*, **52**, 2807 (1933), **53**, 301 (1934).
- Carman, P. C., *Trans. Inst. Chem. Engrs. (London)*, **15**, 150 (1937).
- Carman, P. C., *Trans. Inst. Chem. Engrs. (London)*, **16**, 168 (1938).
- Carman, P. C., *Faraday Soc., Discussions*, No. 3, 72 (1948).
- Carman, P. C., *J. Soc. Chem. Ind.*, **57**, 1, 225 (1938), **58**, 11, 1 (1939).
- Carman, P. C., and J. C. Arnell, *Can. J. Research*, **A26**, 128 (1948).
- Carman, P. C., and P. Le R. Malherbe, *J. Soc. Chem. Ind.*, **69**, 134 (1950).
- Childs, E. C., and N. Collis-George, *Proc. Roy. Soc. (London)*, **A201**, 392 (1950).
- Coulson, J. M., *Trans. Inst. Chem. Engrs. (London)*, **27**, 237 (1949).
- Crone, H. G., and R. F. McKee, *Brit. Coal Utilisation Research Assoc.*, **14**, 329 (1950).
- Dalla Valle, J. M., and others, *Textile Research J.*, **20**, 676 (1950).
- Dobry, A., *J. chim. phys.*, **47**, 402 (1950).
- Dodd, C. G., J. W. Davis, and F. D. Pidgeon, *J. Phys. & Colloid Chem.*, **55**, 684 (1951).
- Durwez, P., and L. Green, *J. Applied Mechanics*, **18**, 39 (1951).
- Durwez, P., and L. Zwell, *J. Metals*, **1**, 137 (1949).
- Elton, G. A. H., *Proc. Roy. Soc. (London)*, **A194**, 259, 275 (1948); **A197**, 568 (1949).
- Emersleben, O., *Physik. Z.*, **26**, 601 (1925).
- Fair, G. M., *J. Inst. Water Engrs.*, **5**, 171 (1951).
- Fair, G. M., and L. P. Hatch, *J. Am. Water Works Assoc.*, **25**, 1551 (1933).
- Furnas, C. C., *U. S. Bur. Mines Bull.*, No. 307 (1929).
- Hatch, L. P., *J. Applied Mechanics*, **7**, A109 (1940).
- Heertjes, P. M., *Research*, **3**, 254 (1950).
- Iberall, A. S., *J. Research, Natl. Bur. Standards*, **45**, 398 (1950).
- Keyes, W. F., *Ind. Eng. Chem., Anal. Ed.*, **18**, 33 (1946).
- Kozeny, J., *Sitzber-Akad. Wiss. Wien, Math. naturw. Klasse*, **136**, 11a, 271 (1927).
- Lea, F. M., and R. W. Nurse, "Symposium on Particle Size Analysis," Supplement to *Trans. Inst. Chem. Engrs. (London)*, **25** (1947).
- Lecuir, R., *Compt. rend.*, **226**, 191 (1948).
- Lipson, H., *Powder Met. Bull.*, **5**, 52 (1950).
- Lewis, W. K., and others, *Chem. & Met. Eng.*, **27**, 594 (1922).
- Lewis, W. K., and C. Almy, *Ind. Eng. Chem.*, **4**, 528 (1912).
- Martin, J. J., Sc. D. Thesis, Carnegie Institute of Technology, Pittsburgh, Pa. (1948).
- Mason, S. G., *TAPPI*, **33**, 403 (1950).
- Miller, S. A., *Chem. Eng. Progress*, **47**, 497 (1951).
- Muskat, M., "The Flow of Homogeneous Fluids Through Porous Media," 1st ed., Chap. 2, McGraw-Hill Book Company, Inc., New York, 1937.
- Muskat, M., R. D. Wyckoff, H. G. Botset, and D. W. Reed, *Rev. Sci. Instruments*, **4**, 394 (1933).
- Robertson, A. A., and S. G. Mason, *Pulp & Paper Mag. Can.*, **50**, 103 (1949).
- Rose, H. E., *Inst. Mech. Engrs. London, Proc., Applied Mech.*, **153**, 141 (1945).
- Ruth, B. F., *Ind. Eng. Chem.*, **27**, 708 (1935).
- Ruth, B. F., *Ind. Eng. Chem.*, **38**, 564 (1946).
- Ruth, B. F., G. H. Montillon, and R. H. Montanna, *Ind. Eng. Chem.*, **25**, 76, 153 (1933).
- Spencer, R. S., G. D. Gilmore, and R. M. Wiley, *J. App. Phys.*, **21**, 527 (1950).
- Sperry, D. R., *Chem. & Met. Eng.*, **15**, 198 (1916).
- Sperry, D. R., *Ind. Eng. Chem.*, **20**, 892 (1928).
- Sullivan, R. R., *J. Applied Phys.*, **12**, 503 (1941); **13**, 725 (1942).
- Sullivan, R. R., and K. L. Hertel, *J. Applied Phys.*, **11**, 761 (1940).
- Warren, D., and J. F. Libsch, *J. Metals*, **3**, 774 (1951).
- Wyllie, M. R. J., and W. D. Rose, *Nature*, **165**, 972 (1950).

Discussion

Walter C. Graulich (Filtration Engineers, Inc., Newark, N. J.): I understand that the data were used for pressure filtration equipment. Do you think these formulas and data can be applied to vacuum filtration?

H. P. Grace: The compression-permeability technique and all calculation methods presented can be and have been applied to vacuum-filtration problems. The greatest potential for the compression-permeability method is in the solution of pressure-filtration problems, which involve a much greater latitude in the choice of filtration pressure and where this choice may be very critical. However, we have also found the value of the compression-permeability method to be particularly great with a new material where no previous filtration information is available and the field of filter selection is wide open to both pressure and vacuum equipment. In this case a single compression-permeability run supplies sufficient information for a quantitative comparison of expected performance at operating conditions within the range of both pressure and vacuum equipment.

Presented at A.I.Ch.E. Cleveland meeting

Parts II and III will appear in forthcoming issues.

Design of Full-Scale Continuous-Tunnel Driers

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A new method of designing continuous-tunnel driers is presented, based upon a simple experimental test in which the stock is exposed to the same sequence of drying conditions as would obtain in a full-scale continuous unit. This test directly determines the drying history of the stock as it passes through the proposed drier. The results are substantially independent of any assumptions concerning the mechanism of the drying process. The experimental equipment required is simple and cheap, and the tests may be performed by nontechnical people who have received minimum training.

At the present time the complex mechanisms that control the rate at which the drying of a given material proceeds usually are not amenable to analytical treatment. Consequently, the design of a continuous drier must be based upon experimental data obtained from tests of the material under consideration. Ordinarily, such tests fall into one of two categories:

1. A pilot model of the proposed drier is constructed and tested, and the results are extrapolated for use in the design of full-scale equipment.

2. Samples of the material are dried in a small batch drier with a gas rate sufficiently high to assure that the gas enters and leaves at substantially the same temperature and humidity. The results of a series of tests, each at a different gas condition, then are used to predict the rate at which drying will proceed in the full-scale continuous unit, in which the stock will encounter gas of continuously varying temperature and humidity.

Both these techniques have serious drawbacks. The pilot model is expensive and not easily modified. The extrapolation of the pilot data cannot always be carried out in a sound fashion. The use of constant-driving-force data to predict actual drier performance is based upon two assumptions that in many cases are in error: (a) The instantaneous drying rate is assumed to be a point function of the stock-water content and the gas conditions and independent of the previous drying history, and (b) the stock is as-

sumed to stay at a constant temperature, usually the gas wet-bulb temperature.

Description of Design Method

The design method proposed here circumvents the objections to the older techniques. As the stock moves through a continuous drier, its liquid content and (usually) temperature change. Simultaneously, the drying-gas conditions also change. This continuous variation in both stock and gas properties makes it difficult to predict actual drying rates even when extensive data for constant drying conditions are available. Nevertheless, it is apparent that the stock history in a continuous drier may be duplicated if the stock is fixed in place but subjected to the same continuously varying external drying conditions. This simulation of the actual drying process is the principle of the design method proposed here.

The simulation method is most easily explained if a simple, concrete case is used.

Figure 1 schematically illustrates a continuous, adiabatic, parallel-flow drier. The material balance for the liquid written between the inlet end (1) and a section x feet down the drier is

$$W_1 - W = m(H - H_1) \quad (1)$$

where m is the ratio of pounds of bone-dry gas fed per hour (w_g) to the pounds of bone-dry stock fed per hour (R).

An energy balance written between the same two sections is

$$c(t_1 - t) + c_L[W_1(t_1 - T_r) - W(t - T_r)] = -m\{c_g(T_1 - T) + \lambda_r(H_1 - H) + c_v[H_1(T_1 - T_r) - H(T - T_r)]\} \quad (2)$$

Equation (2) is subject to the following limitations:

1. The specific heats have been considered constant; methods for the removal of this restriction are obvious.

2. The temperatures are taken to be suitable averages. At a given section the gas in a satisfactory drier is well mixed. The interior temperatures of the stock may vary. This variation is seldom serious and, if desired, may be taken into account in the experimental portion of the design procedure.

3. The energy required to vaporize "bound" liquid does not appear in Equation (2). If adsorbed or other combined liquid is removed during the drying process, the energy of desorption should be included in the energy balance. In general, this cannot be done exactly, but a reasonable approximation is possible if it is assumed that the point at which bound liquid begins to be evaporated is determined by an average stock-liquid content.

With these minor limitations, Equations (1) and (2) are rigorous, and the drying process must satisfy these relationships regardless of the mechanism by which the drying takes place.

The object of the design method is to determine the time (and hence the drier length) required to dry the stock from an initial liquid content W_1 and temperature t_1 to a final liquid content W_2 using a gas which enters the drier at a temperature T_1 , humidity H_1 and with a dry-gas-to-dry-stock ratio m . Useful additional information to be obtained is

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the history of both the stock and gas as they pass through the drier. The designer specifies the stock arrangement and the gas superficial mass velocity.

At this stage the design procedure becomes a laboratory experiment. Representative samples of the stock are placed in a laboratory drier in the same manner as proposed for the full-scale unit. A portion of this stock is suspended from a balance or other suitable weighing instrument and provided with thermocouples so that the average stock temperature (or temperature distribution if desired) may be measured. Dry- and wet-bulb thermometers* are placed in the gas passage adjacent to the instrumented stock. A schematic drawing of such a setup is shown in Figure 2.

The stock sample is sufficiently small so that the gas does not undergo a significant change in temperature or humidity in its passage over the sample. The gas supply flows over the stock at the design velocity and initially at the temperature T_1 and humidity H_1 , corresponding to the conditions to be encountered by the fresh stock as it enters the full-scale continuous drier. After a short period of time under these conditions, the change in stock weight and temperature are measured. The gas temperature and humidity which would correspond to these stock conditions in the actual drier are calculated from Equations (1) and (2) and the gas conditions changed accordingly. This process is repeated at short intervals until the liquid content of the stock has been reduced to the final value set by the designer. The time required to achieve this result is the residence time that must be provided in the actual full-scale unit, and the recorded-time history of the stock and gas is also the history of these materials in the full-scale drier.

A series of experiments such as those described above will explore the effect of change in the independent variables at the disposal of the designer. The method is not limited to adiabatic-parallel-flow equipment but is quite versatile. Its application to other conditions including those in which additional heat sources are provided within the drier is discussed in a later section.

Limitations of Method

The experimental technique just described is essentially an analogue computer in which the actual drying procedure is used to circumvent the limitations imposed by an inadequate knowledge of the drying process. It is inferior to an electronic computer in the speed with which information is obtained and in the size of the time increments that must be used. On the other hand, not enough is known about the drying mechanism to construct an electric analogue. It is of course possible to make the experimental operation automatic and obtain a con-

* Any suitable humidity- or temperature-measuring devices may be used.

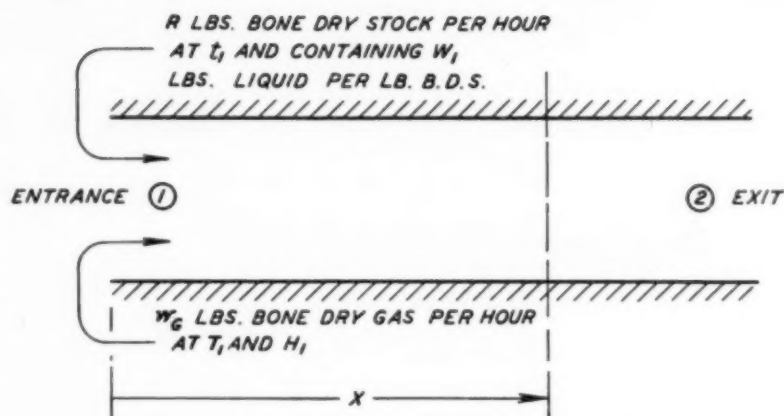


Fig. 1. Schematic illustration of a continuous adiabatic, parallel-flow drier.

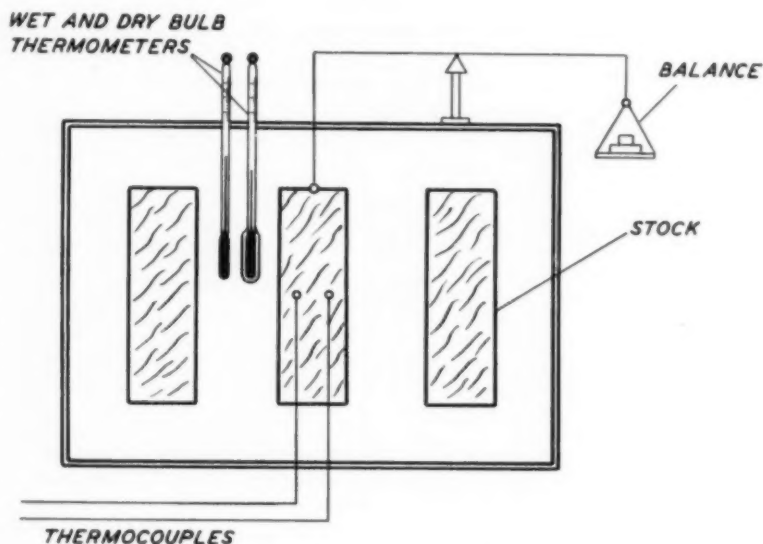


Fig. 2. Cross section of experimental drier arranged for design tests.

tinuous rather than a stepwise variation in the gas properties with a change in stock conditions if suitable control and computing equipment is installed in the laboratory drier. Such complications are scarcely justified. In practice it is found that the time increments between gas-condition adjustments can be several minutes without incurring significant error.

The experimental setup must be arranged to simulate the operation of the proposed full-scale unit. The gas-flow pattern, the location of heat sources or sinks, and the position of adjacent stock samples should correspond to the plan for the industrial drier. If practicable, full-size portions of the stock should be used in the tests. If the test samples are smaller than the full-scale stock units, edge and Reynolds-number effects may introduce errors.

In a small sample the edge area of the stock may be a much larger fraction of the total area than is the case with stock of industrial size. Unless this is recognized and compensated for by adequate vapor and thermal barriers, the observed sample drying rate may differ from the rate achieved with full-size stock.

The heat- and mass-transfer coefficients for the exchange processes between the gas and stock are functions of the system geometry and Reynolds number. The tests should be carried out under conditions such that geometric and dynamic similarity is obtained between the experiments and the proposed full-scale drier conditions. If exact similarity cannot be achieved, it may be necessary to run a series of tests in order to determine the effect of changes in the scale variables and then to extrapolate

the test results to the full-size drier. These scale problems are of course encountered whenever small samples are used to predict full-size equipment performance.

Application to Other Drying Operations

As an example of the application of the proposed simulator design procedure to other drying operations, consider the case of a counterflow nonadiabatic drier. Let q_x represent the net heat added from the system per pound of bone-dry stock per foot of drier length. This heat might be added by infrared radiation, "reheat" of the drier gas, etc., or might be lost through the drier walls, etc.

The counterflow material balance on the liquid is

$$W - W_1 = m(H - H_1) \quad (3)$$

and the energy balance is

$$c(t - t_1) + c_L[W(t - T_r) - W_1(t_1 - T_r)] = \int_0^\theta (q_x) L_R d\theta + m \left[c_g(T - T_1) + \lambda_r(H - H_1) + c_v[H(T - T_r) - H_1(T_1 - T_r)] \right] \quad (4)$$

where L_R is the lineal velocity at which the stock moves through the drier and θ is the time required for the stock to travel from the drier inlet to the point where the stock-liquid content is W . Both L_R and q_x are ordinarily set by the designer and, of course, may be functions of the distance from the drier inlet, which is

$$x = \int_0^\theta L_R d\theta.$$

When q_x is negative, representing heat loss, it can be related to the gas dry-bulb temperature, gas-flow conditions, etc., by the usual heat-transfer expressions.

The experimental determination of the drying time for the countercurrent nonadiabatic case now proceeds in the same manner as that discussed earlier for the parallel-flow adiabatic system. The experimental drier must be arranged so that the heat addition or loss simulates that proposed for the full-scale design. This usually implies a carefully worked out experimental setup.

The extension of this design technique to many other drying and related operations is apparent and will not be examined in detail here.

* The subscript (1) refers to the end of the drier at which the stock enters. In a counterflow drier this is the end at which the gas leaves.

Comparison of New and Point-Drying-Condition Methods

The point-drying-condition method as proposed by Walker, Lewis, McAdams and Gilliland (5) is as follows:

A sample of the wet stock is placed in an experimental drier in a manner which simulates the geometry of the proposed full-scale drier. The sample is then dried with constant-temperature and -humidity gas flowing over the sample at design velocity. Measurements are made of the rate of evaporation as a function of the liquid content of the stock. The experimental data are then plotted as $-(dW/Ad\theta)$ vs. W for the particular gas conditions employed, as shown in Figure 3. A series of such runs is carried out. In each run a different gas dry-bulb temperature and humidity are employed, but the same gas wet-bulb temperature is used in all cases. In this way the family of curves shown in Figure 3 is obtained. Each curve represents the drying rate for a fixed humidity difference, $\Delta H = H_w - H$, and this is the parameter used to characterize the curve.

During the constant-rate drying period the stock temperature equals the bulk-gas wet-bulb temperature and the humidity of the gas in contact with the stock surface is H_w , the value corresponding to saturation at the bulk-gas wet-bulb temperature. Under these conditions, the humidity difference $H_w - H$ is the actual driving force causing mass transfer of the liquid vapor from the solid surface to the main gas stream. In the falling-rate period, the stock surface temperature is greater than the bulk-gas wet-bulb temperature, and the humidity of the gas in immediate contact with the stock surface is less than H_w . These effects result from the finite resistance to mass transfer within the solid which

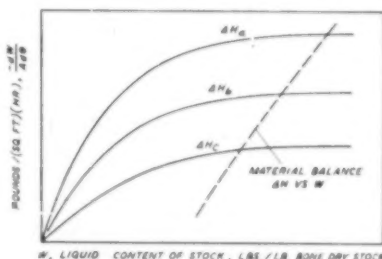


Fig. 3. Data used in point-drying-condition method.

is associated with the falling-rate period. However, under certain circumstances the drying rate is still proportional to the humidity difference $H_w - H$, where H_w corresponds to saturation at the bulk-gas wet-bulb temperature. Unfortunately, the conditions under which the drying rate in the falling-rate period is proportional to $H_w - H$ are very limited.

Usually, to fulfill these conditions the drying must proceed in such a way that the liquid remains at the bulk-gas wet-bulb temperature, and the evaporation zone merely regresses from the gas-stock interface to positions in the interior of the solid.

If the drying rate is proportional to $H_w - H$ and H_w remains constant, the material-balance curve representing the relation between $H_w - H$ and the stock-liquid content in the continuous drier [obtained from Equations (1) and (3)*] may be drawn on the drying-rate chart obtained from the constant-gas-condition tests as shown on Figure 3. If the drying rate is actually a point function of W and $H_w - H$, the material-balance curve on Figure 3 also represents the relation between the drying rate $-(dW/Ad\theta)$ and the stock-liquid content for the drier under consideration. For this condition, the integral

$$\frac{1}{A} \int_{W_1}^{W_2} \frac{-dW}{\left(\frac{dW}{Ad\theta} \right)} = \theta,$$

the required drying time.

The point-drying-condition design method outlined above is frequently used when one or more of the special conditions required by its derivation are not fulfilled. Indeed, the requirements are so severe that a large number of the cases met in practice fail to meet its standards and the point-condition method is often a poor way to estimate the required drying time.

The drying times predicted by the simulator method and by the conventional point-drying method were compared in a series of tests made in the chemical engineering laboratories of the Massachusetts Institute of Technology. Two types of stock were used: porous materials (insulite board and china clay), for which the point-drying-condition assumptions would be expected to be approximately fulfilled, and a casehardening material (soap), for which the point-drying method would be expected to fail.

POROUS STOCK EXPERIMENTS

Jayaraman and Rossen (3) compared the drying times predicted by the simulator method and by the conventional point-drying method for both countercurrent and parallel flow using as stock 6-by-6-by-1-in. slabs of insulite sheathing, a fibrous insulating board. Samples were prepared by saturating under water in a periodically evacuated container until no further weight gain occurred. The slabs were then fitted snugly

* Thus, if H_w is regarded as constant, Equation (1) may be rearranged to give

$$W - W_1 = m[(H_w - H) - (H_w - H_1)] \quad (5)$$

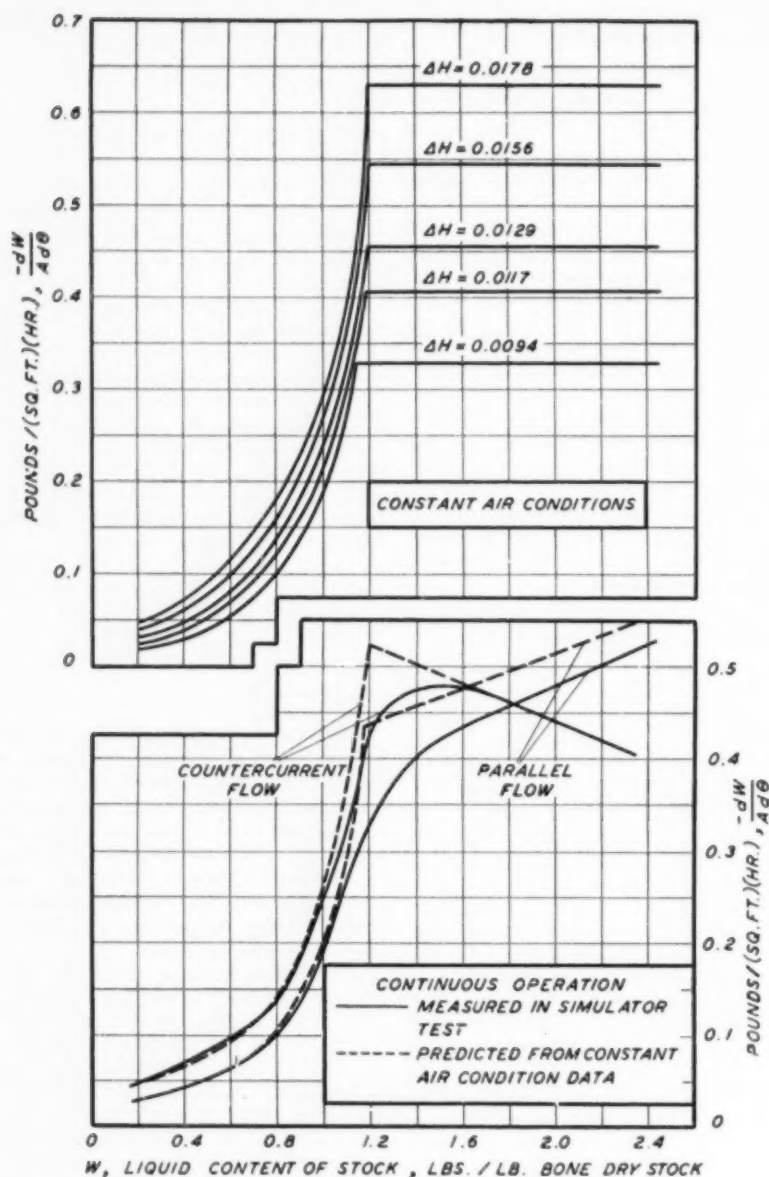


Fig. 4a and b. Drying rate of insulite board—data of Jayaraman and Rossen (3).

into varnished wooden frames, so that no edge drying would occur. Constant-air-condition curves are shown in Figure 4a for the air conditions of Table 1.

TABLE 1

$V_A = 20$ ft./sec., $T_w = 90^\circ$ F., $H_w = 0.312$ lb./lb. bone-dry air, $A = 1.64$ sq.ft./lb. bone-dry stock in all tests.

T_2 , ° F.	H_2 , lb./lb.	$H_w - H_2$, lb./lb.
160	0.0134	0.0178
150	0.0156	0.0156
142.5	0.0183	0.0129
135	0.0194	0.0118
125	0.0218	0.0094

The two design methods were applied to a case of adiabatic countercurrent drying at an air velocity of 20 ft./sec., for which the following terminal conditions and air-stock ratios were chosen: $W_1 = 3.10$, $W_2 = 0.16$, $t_2 = 90^\circ$ F., $T_1 = 125^\circ$, $H_1 = 0.0218$, $m = 350$. By over-all heat and water balances [Equations (3) and (4)] the following additional terminal conditions were calculated using $c = 0.30$, $T_2 = 160^\circ$ F., and $H_2 = 0.0134$.

It will be noted that for countercurrent flow, to calculate exactly the temperature at which the air should enter in order to leave at the conditions speci-

fied, it is necessary to know the temperature at which the stock leaves. This is generally unknown. For this case, however, the heat capacity of the stock is so low compared with that of the air stream, that no significant error is introduced into the calculation of T_2 . In general, application of the simulator method to countercurrent operation requires assumption of the conditions at which the air leaves the drier. Application of the test method then leads to the actual temperatures at which the stock leaves and at which the air must enter, and these cannot be predicted exactly beforehand.

In these experiments, the value of m , the air-to-stock-mass ratio, deliberately was made unusually large in order that the air enthalpy and wet-bulb temperature might remain essentially constant throughout the drying operation. In this way, the conditions necessary for the point-condition-drying method to be valid were more closely approached than is usually the case.

For the parallel-flow case, the assumed terminal conditions were $V_A = 20$, $W_1 = 3.10$, $W_2 = 0.16$, $t_1 = 90^\circ$ F., $T_1 = 160^\circ$, $H_1 = 0.0134$, and $m = 350$. The calculated additional terminal conditions were $T_2 = 125^\circ$ F. and $H_2 = 0.0218$.

In the simulator tests, air conditions were readjusted every 15 min. The technique was refined somewhat by projecting required air conditions ahead by a half period, so that no consistent lag in air conditions existed.

Drying-rate curves for the parallel- and countercurrent cases, as calculated by the conventional method and as observed in the simulator tests (average of duplicate tests), are shown in Figure 4b. The times required for drying in the constant-rate and falling-rate periods and the totals are compared in Table 2.

The deviations in the total required time are well within experimental accuracy.

These experiments show that when the stock and gas conditions are selected in a fashion designed to fulfill the assumptions of the point-drying-condition method, this method and the simulator technique predict essentially the same drying times. Equally good agreement between the two design techniques was observed by Knox (4) and Aiken (1) in the course of tests of the drying rates of china clay under circumstances in which the point-condition method would be expected to hold.

CASEHARDENING EXPERIMENTS

The conventional point-condition design method would be expected to fail most drastically for materials in which internal resistance to water movement is high, as evidenced by extended falling rate zones and casehardening. Brodersen and LaBelle (2) have investigated soap as being

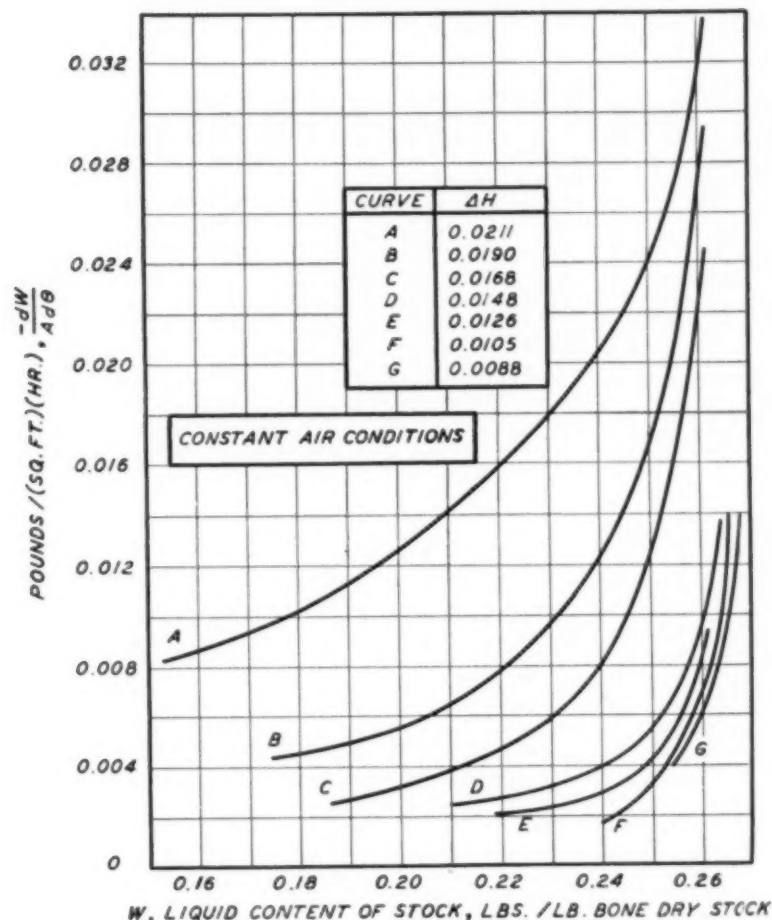


Fig. 5. Drying rate of soap—data of Brodersen and La Belle (2).

TABLE 2
DRYING TIME

Time in drier, hr.	Countercurrent			Parallel		
	θ_c	θ_F	θ_T	θ_c	θ_F	θ_T
Predicted by conventional method	2.68	5.83	8.51	2.23	10.07	12.30
Observed in simulator test	2.74	5.85	8.59	2.38	10.16	12.54

typical of this type of material. A bar-type soap, having a water content W of 0.268 as received was heated in a sealed container at about 160° F. to soften and was then pressed into wood frames to form slabs 5 by 2½ by ½ in. The large faces were cut flush with the frame with a piano-wire cutter just prior to drying. Multiple thermocouple junctions were inserted into the sample through the frame edges to measure sample temperature. To reduce radiation effects from the drier walls two masking frames 9 by 6½ by ½ in. filled with soap were similarly placed in the drier walls, 1 in. from each side of the test frame during runs. The heat capacity, c , of the bone-dry soap was 0.64 at its average temperature during drying.

Drying curves for constant-air-condition tests are given in Figure 5 for the conditions shown in Table 3.

A simulated adiabatic countercurrent drying test was then made using terminal conditions and air-stock ratio as follows: $W_1 = 0.268$, $W_2 = 0.156$, $T_1 = 134.6^\circ$ F., $H_1 = 0.0330$, $t_1 = 98.6^\circ$ F., and $m = 9.13$. Under these conditions, the heat capacity of the dry stock is no longer negligible compared with that of the air. Consequently, the temperature of the air entering cannot be calculated unless the temperature of the stock leaving the drier is known.

TABLE 3

$V_A = 20$ ft./sec., $T_w = 98.6^\circ$ F., $H_w = 0.0412$ lb./lb. bone-dry air, $A = 1.07$ sq.ft./lb. bone-dry stock in all tests.

T , ° F.	H , lb./lb.	$H_w - H$, lb./lb.
187	0.0201	0.0211
178	0.0222	0.0190
169	0.0244	0.0168
160	0.0264	0.0148
151	0.0286	0.0126
142	0.0307	0.0105
134.6	0.0324	0.0088

The conventional point-condition-design method assumes that the wet-bulb temperature of the air stays constant throughout the drier and that the stock remains at wet-bulb temperature. The variations of stock temperature, air temperature, air humidity, and $H_w - H$ with water content as calculated conventionally are shown as dashed curves in Figure 6. In contrast, the actual variation in these quantities, as determined in the simulator test, are shown by solid lines on the same graph. It is seen that the sample temperature actually remains within a few degrees of the dry-bulb temperature of the air.

If the conventional-point-design procedure is continued in standard fashion, it is predicted that drying could be accomplished in 31.0 hr. by air entering at 187° F. However, from Figure 6 it can be seen that the water content of the stock could not have been reduced below $W = 0.20$ by air entering at this temperature, and to carry out the desired removal of moisture, air entering at 209° F. is required. Consequently, the conventional design procedure is completely inadequate.

A possible modification, based upon a posteriori information, of the conventional design procedure might have been to assume that the stock would always be about 3° F. below the air dry-bulb temperature. If this had been done, the variation of air and stock conditions through the drier could have been calculated by heat and material balances and would have approximated closely the actual variations as shown by the solid curves of Figure 6. The adequacy of this design method would then have been dependent on how nearly drying rate was a point function of W and ΔH .

To illustrate the latter, the actual drying rate vs. water content as measured in the simulator test is plotted as a solid curve in Figure 7a. On the same graph, the broken curve shows the rate that would have been predicted on the assumption that drying rate was a point function of W and ΔH , using the values of ΔH actually obtaining in the simulator test. This curve cannot be extended

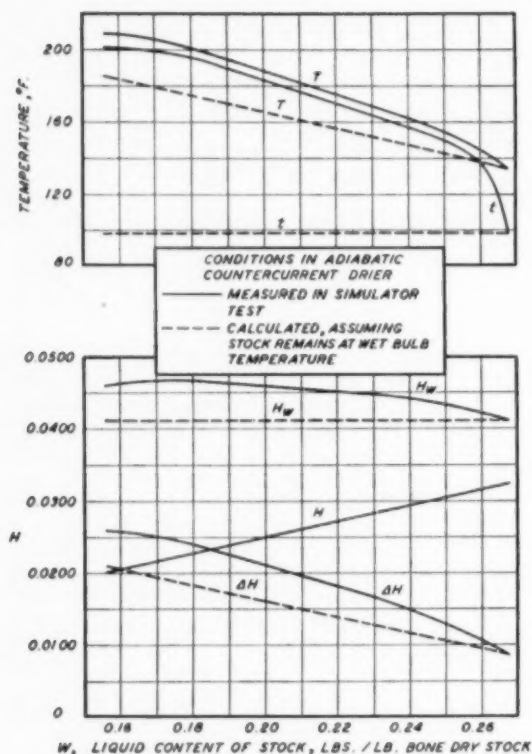


Fig. 6. Drying of soap, variation of stock and air—data of Brodersen and La Belle (2).

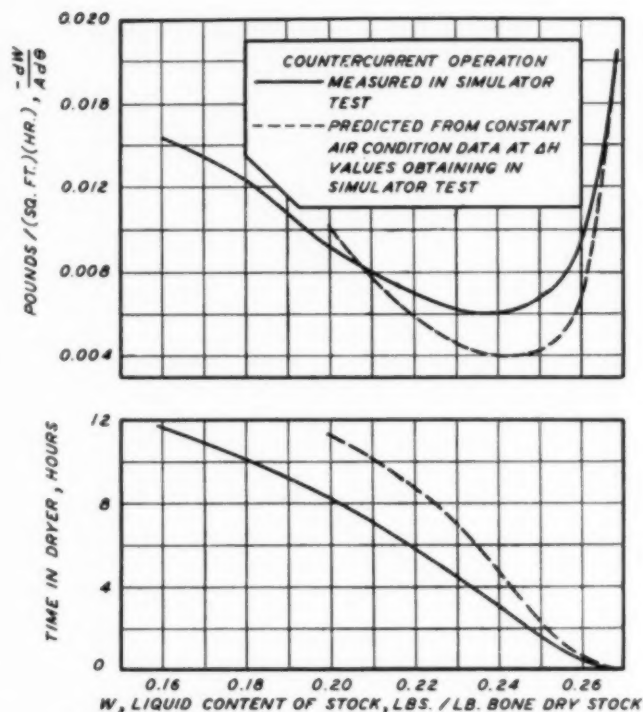


Fig. 7a and b. Drying rate of soap—data of Brodersen and La Belle (2).

to the final water content, because the constant-air-condition data do not extend to sufficiently high values of ΔH . It is obvious, however, that the two rate curves are in poor agreement.

In Figure 7b the required residence time in the drier is plotted as a function of the stock-water content. The solid curve is the time measured in the simulator test, while the dotted line was obtained by integration of the rate data corresponding to the dotted line of Figure 7a and calculated by assuming the drying rate to be a point function of W and ΔH . The drying times predicted by the two methods disagree significantly.

For a stock of this type, it thus appears that the conventional design method breaks down for two basic reasons: (1) Drying rate is not a point function of W and ΔH , and (2) the variation in stock temperature cannot be predicted. Hence, at low air-stock ratios, it is impossible to predict variation in air temperature through the drier. The simulator type of design test avoids these difficulties completely.

Acknowledgment

The authors wish to acknowledge the material aid given this study by the thesis students listed in the Literature Cited. Constructive criticism offered by

professional colleagues, in particular by Professors W. H. McAdams and R. F. Baddour, was most stimulating. Mr. H. H. Carter prepared the drawings.

Notation

- A = exposed area of stock, sq.ft./lb. bone-dry stock
- c = specific-heat dry stock, B.t.u./lb. (° F.)
- c_g = specific-heat carrier gas at constant pressure, B.t.u./lb. (° F.)
- c_v = specific heat of evaporated liquid vapor at constant pressure, B.t.u./lb. (° F.)
- c_l = specific heat of liquid, B.t.u./lb. (° F.)
- H_w = humidity of carrier gas if saturated at wet-bulb temperature, lb. vapor/lb. carrier gas
- H = humidity, lb. vapor/lb. carrier gas
- $\Delta H = H_w - H$
- $m = w/R$
- q_a = heat added, B.t.u./ft. of drier length (lb. bone-dry stock)
- R = stock feed rate, lb. bone-dry stock/hr.
- T, T_w = gas temperature, dry and wet bulb, ° F.
- t = stock temperature, ° F.
- T_r = reference temperature, ° F.
- V_s = gas velocity, ft./sec.
- V_R = linear velocity of stock through drier, ft./hr.
- w_G = mass flow rate of carrier gas, lb./hr.

W = liquid content of stock, lb. liquid/lb. bone-dry stock

θ = time, hr.

λ_r = heat of vaporization of liquid at reference temperature, B.t.u./lb.

SUBSCRIPTS

- 1 = end of drier at which stock enters (drier inlet)
- 2 = end of drier at which stock leaves (drier outlet)
- C = constant-rate period
- F = falling-rate period
- r = reference condition
- T = total drying period

Literature Cited

1. Aiken, D. P., B.S. Thesis in Chemical Engineering, Massachusetts Institute of Technology, Cambridge (1947).
2. Brodersen, C. F., and F. P. LaBelle, M.S. Thesis in Chemical Engineering, Massachusetts Institute of Technology, Cambridge (1951).
3. Jayaraman, R., and J. N. Rossen, M.S. Thesis in Chemical Engineering, Massachusetts Institute of Technology, Cambridge (1949).
4. Knox, H. E., Jr., M.S. Thesis in Chemical Engineering, Massachusetts Institute of Technology, Cambridge (1947).
5. Walker, W. H., W. K. Lewis, W. H. McAdams, and E. R. Gilliland, "Principles of Chemical Engineering," McGraw-Hill Book Co., Inc., New York, 1937.

INFORMATION TRANSFER

—a new unit operation?

Marshall Sittig Ethyl Corporation, Detroit, Michigan

What is your coefficient of information transfer? Are you getting your story across? Doing a good technical job is not enough. Selling the results of that job determines your status with your employer, your fellows, and the public.

The chemical engineer can consider the problem of communication as one of information transfer. Information transfer should be a basic tool, along with heat and material transfer. Indeed, the results of chemical engineering studies of heat or material transfer may be unheard or misunderstood because of lack of effective information transfer. The essentials of effective communication for the engineer are

1. Accurate data based on good research work and organized files.
2. Competent writing and illustrating talent.
3. Equipment and organization for effective and economical reproduction.

Broadly, there are four methods of transferring information: the written word, illustration, three-dimensional models, and the spoken word.

Writing

Engineers may be called upon to present detailed technical data to other engineers or to "sugar-coat" the information so that the uninformed layman can swallow it. These problems call for tools ranging from Greek letters to comic books. Demmerle has given an excellent summary of the means used to convey an idea (3); his illustration of the spectrum of communications is shown in Figure 1. The progression across the spectrum is from extremely simplified presentations such as comic books, through popularized science writing, which includes press releases as well as descriptions of scientific subjects in popular journals for the average reader,

to the more technical literature—articles, reports, and books.

For the technical article or report—by engineers, for engineers—the over-all format of the report is usually set by an organization style manual. The style manual of the Hercules Powder Company is a good example and has recently been reprinted in full (5). Another type of style manual is the set of directions issued by a technical society, such as the "Guide to Authors" published by the A.I.Ch.E., "Hints to Authors" published by the A.C.S., "An A.S.M.E. Paper" published by the A.S.M.E., and "Editorial Style" published by the A.P.I.

Once the format of the report is established, there is the problem of setting down the words. Walter B. Pitkin has been quoted as saying, "The scientist is the only one who has anything worth saying, and he doesn't know how to say it." W. T. Nichols on the other hand has pointed out (8) that writing skill is based largely on a thorough knowledge of the subject at hand. As one moves

across the spectrum from technical to nontechnical presentations, a good fundamental grasp of the subject becomes more and more essential.

Also essential is a knowledge of the art of writing. In this case there is not implied a detailed knowledge of school-book English, including gerunds and the like. Rather, the term means readability, a measure of the "viscosity" of the text. As one approach to readability, Rudolf Flesch (4) has developed what he calls a reading-ease score, R :

$$R = 206.835 - 1.015N - 0.864S$$

where

R = reading-ease score (0 being difficult, 100 easy)

N = number of words/sentence

S = number of syllables/100 words

Formidable as this may seem, its application is really very simple. Table 1 illustrates the results for a range of familiar publications.

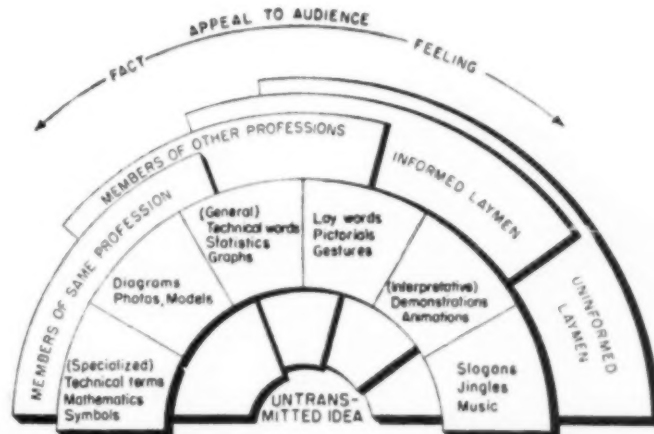


Fig. 1. The spectrum of communications.

Table 1

Publication	Reading-ease score
First-grade reader	97.5
Eighth-grade book	72
Twelfth-grade book	63
Readers Digest	56
Saturday Evening Post	52
This paper	32

Perhaps the best description of Flesch's formula, aside from Flesch's own books, is found in "Gobble-de-Gook or Plain Talk," a booklet prepared by the Air Materiel Command for its own personnel. General Motors has prepared a pocket calculator for the ready application of the Flesch formula to its employee publications.

The basic requirements of technical writing are

Accuracy	Consistency
Brevity	Interest
Clarity	Completeness

Accuracy, consistency, and completeness are taken for granted in a technical paper. Brevity and clarity are associated with Flesch's readability score. Then comes the question of how interesting a piece of technical writing is. It is suggested that chemists and engineers give more thought to the human interest of their written products. Human interest may be unnecessary in "A Report on the Effect of Sulfuric Acid Concentration in the Nitration of 2,4-Dichlorophenol," but it may do wonders for a new product brochure or for a set of plant-operating instructions. Most technical writing manuals teach that the use of anything other than the third person is a scarlet sin. Depending on the audience, this prohibition need not apply so strongly.

It has been said that everything that is written is meant either to please or to instruct, and that the second object is difficult to effect without attending to the first. Dr. Flesch has presented the concept of "personal words" and "personal sentences" to calculate the interest of a piece of written matter:

$$I = 3.635 H' + 0.314 S$$

where

I = human-interest score (0 having no human interest, 100 being full of human interest)

H' = number of personal words (pronouns and words having gender such as *father*, *sister*, *iceman*, *actress*)/100 words

S = number of personal sentences (direct address, questions, commands, requests, exclamations)/100 sentences

Application of the human-interest score to magazines gives some interesting results, as cited by Flesch:

Description of style	Personal words, %	Personal sentences, %	Human-interest score	Typical magazines
Dull	2	0	0-10	Scientific
Mildly interesting *	4	5	10-20	Trade journals
Interesting	7	15	20-40	Digests
Highly interesting	10	43	40-60	New Yorker
Dramatic	17	58	60-100	Fiction

* This article rates in this bracket.

Readability may be improved by mechanical devices as well as by proper use of language. One interesting device proposed recently is "square-span" reading (1):

It may best be described	by an actual example.	Square-span reading	looks like this.
It may be hard to print	but reading words in groups	comes easily to most people.	

This arrangement is particularly applicable to lantern-slide copy.

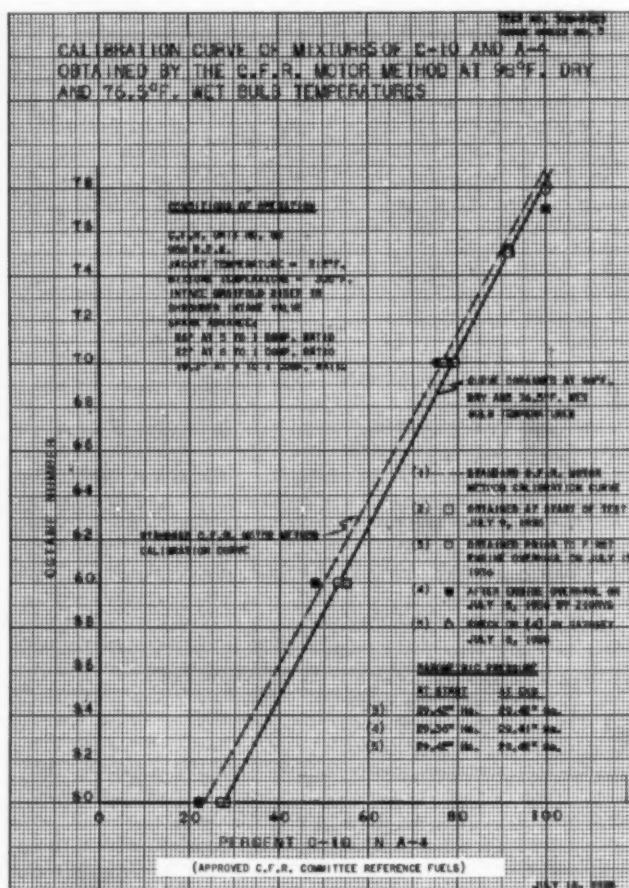


Fig. 2a. A poor graph.

Thorough technical knowledge, consciousness of Flesch's principles, the use of special devices such as square-span reading, all combine to give clarity. Another good way of improving written

reports is to study the work of experts in the interpretation of science. Among these experts are Edwin Slosson, author of "Creative Chemistry"; George Russell Harrison, author of "Atoms in

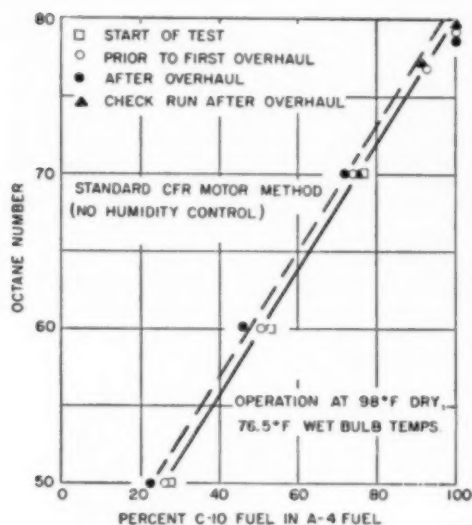


Fig. 2b. A good graph.

Action"; W. H. Lawrence, New York Times science reporter and unofficial interpreter for the Atomic Energy Commission; Wolfgang Langewiesche, an engineer who flies and describes aviation to the public; George W. Gray, author of "The Advancing Front of Science"; and R. M. Chapin, who prepares maps and diagrams for Time Magazine.

Illustration is

Once the text is organized in simple, readable language, there remains the question of how to illustrate it.

Perhaps the most common report illustrations are graphs. Figures 2a and 2b show how—and how not—to present data graphically.

A second type of report illustration is the equipment drawing or flow sheet. The acetate overlay is a very effective device for sketches of equipment or sequences in an operation. The internal working of apparatus may be disclosed by this technique, as shown in Figure 3.

The third type of report illustration is the photograph. Here a standardized title block is often used to ensure the appearance of vital data about the photograph. Necessary precautions in the preparation of report photographs include the provision of a ruler or other reference in the picture to give the reader the proper scale. Useful unusual photographic techniques include the use of a double exposure to show two distinct stages of an operation in a single photograph.

Printing

Along with the preparation of a skillfully written and illustrated text comes the question of the mechanics of printing the text and, subsequently, of duplicating the printed text and the illustra-

tions. The methods available for printing the text include

Standard typewriter—easily available

IBM electric typewriter—better quality

Varityper—variety of type faces

Typeset text—best appearance but most expensive

Among the methods of creating special captions or of lettering on graphs and charts are

Lettering templates

Artype or Fototype—letters must be individually mounted

The following duplicating methods produce satisfactory reports:

Hectographing (Ditto)

Stenciling (Mimeograph)—illustrations are difficult

Blue-line and black-line (Ozolid)—offers broader opportunities for illustration, but more expensive than foregoing methods



Fig. 3. Acetate overlays.

Milprint, Inc.

Photostat—expensive, but useful for limited quantities of opaque material

Offset lithography (Multilith)—gives clear reproduction of printed matter and illustrations

Letterpress—this is "conventional" printing

Xerography—very rapid (and quite inexpensive when combined with Multilith)

Binding

Binding a report seems simple and obvious. Stapling the report together (running a strip of binding tape down the stapled edge) is the commonest and cheapest method. Although mechanical (plastic and wire) bindings are more expensive, they look better in many cases and have special advantages. Such mechanical bindings offer a book which always lies flat when open, a backbone (plastic) that will take printing, complete visibility in that no part of the page is hidden within the binding, and

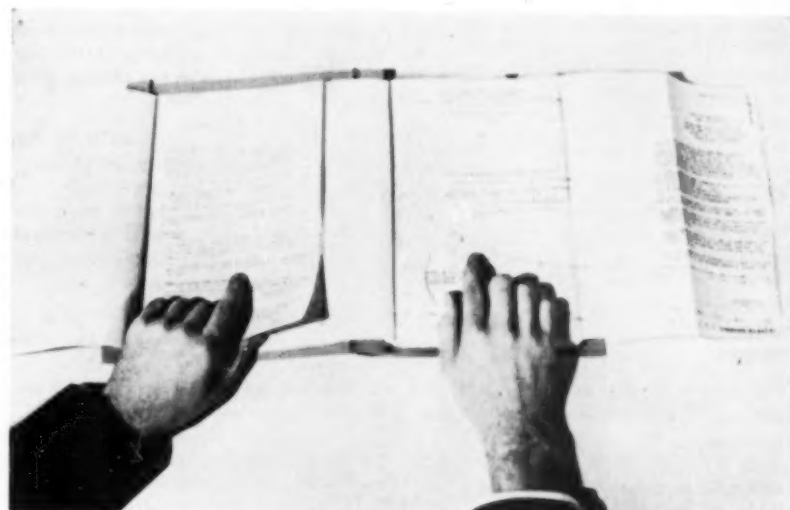


Fig. 4. Report-binding technique.

General Electric Co.

ease of addition and removal of pages.

An interesting binding technique, but not a widely used one, is that described by Horn (6). Here, as shown in Figure 4, the text pages are bound inside the front cover while illustrations pertinent to the text are bound at the fold in the center of the cover. This method permits good correlation of text and illus-

Lantern slides are commonly used as accompaniment to the presentation of technical papers. They are also commonly misused for this purpose. The various technical-society publications have suggestions and requirements for slide preparation, and a comprehensive discussion is offered by Jones (7). Current concern over quality control of

out and encircle items on the slide with a pencil without using a long rod or flashlight.

5. The image is so brilliant that these projectors may be used in semidarkened rooms, permitting note-taking by the audience.

6. Lecture demonstrations can be conducted in alternation with slides if desired. The electro-motive series, for example, may be demonstrated by placing a flat glass dish containing acid over

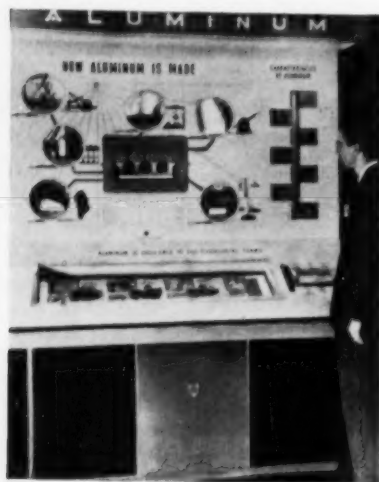


Fig. 5. Exhibit display panel.



Fig. 6. Flip-over presentation.

Jan. Hardy

trations by the reader.

Visual Aids

The use of visual aids in one form or another is essential to the technical article. Pictures as report illustrations have already been discussed, and projected pictures, films, etc., will be considered below. Displays are another important outlet. They may take the form of exhibits at technical society meetings, equipment expositions, etc. (see Fig. 5), or they may be flip-over presentations of the type commonly used in safety meetings and sales work (see Fig. 6). Still another useful visual aid is the flannel board, which offers a modern adaptation of the old Chautauqua chalk talk (see Fig. 7).

Projected pictures include (in approximate increasing order of complexity):

- Stereopticons or opaque projectors
- Lantern slides
- Vu-Graph or Visual-Cast (overhead) projectors
- Film strips
- Movies
- Television

Opaque projectors are of limited usefulness. However, they are inexpensive in themselves and least expensive as regards preparation of material for projection, since books, magazines, and single printed sheets may be used directly.

slides is evidenced in suggestions that authors be required to submit their slides at the same time that papers are submitted for approval prior to presentation at technical society meetings.

Important points cited by Jones include the following:

1. Use of a semidarkened auditorium to avoid the visual shock resulting from alternating a pitch-dark room and a glaring white screen (see also point 3).
2. Use of a minimum lettering size, 1/30 of the over-all height of the slide original. Various authorities specify much smaller sizes than this as acceptable (but the A.I.Ch.E. "Guide to Speakers" specifies 1/32, which is quite close).
3. Use of negative slides because of lower cost, easier application of color, and pleasing optical effect in a semidarkened room.

A new and little used device is that for the overhead projection of large transparencies. The Vu-Graph and Visual-Cast are examples of such machines. They offer several advantages over conventional slide projectors (see Fig. 8):

1. The speaker can face the audience as he operates the projector. He need not look at the screen at all.
2. Successive transparencies may be used to give effective overlay effects.
3. The "strip-tease" technique may be used to disclose portions of a slide progressively, as they are discussed, concentrating the audience's attention and preventing it from wandering.
4. The speaker, facing the audience, can point

the horizontal slide support and placing samples of various metals next to their symbols, written on the dish with a wax pencil. The relative activities of the various metals are instantly visualized.

7. The slides are light in weight (since only a single plastic film and no glass is involved), making them easy to transport. Their size and unbreakability permit filing with the accompanying text in a conventional letter file.

Film strips are a widely used device in industrial and military training work. Motion pictures are of obvious value. They can be used to depict sequences in processes as other picture forms are unable to do.

Television is, of course, the medium of the day. The subject of televising chemistry has been discussed by M. H. Baker (2).

Models are not usually considered as media for information transfer but, properly used, they may be one of the most effective means available. They may be used in advertising and sales—in the presentation of a new plant layout in palatable form in magazine advertising, for example. They may be used in the presentation of a model of a proposed piece of equipment to a board of directors for approval. Architects have long used models in the presentation of designs to prospective clients. Alert chemical design engineers are now following their lead (see Fig. 9). An interesting use of models was that made recently in the presentation of the design



Fig. 7. Flannel board in use.

Florenz, Inc.



Fig. 8. Vu-Graph in use.

Charles Beeler Co.

of the new United Nations skyscraper to the delegates—who speak fifty-eight different languages—in the form of a model, which speaks the universal language.

Speaking

The spoken word is also very important in information transfer. The A.I.Ch.E. offers its "Guide to Speakers" as a contribution to better oral presentations. Some tips on public speaking for chemical engineers are also presented by Seinwerth (9). An additional point is the usefulness of the tape or wire recorder in rehearsing an oral presentation. By use of such a recorder, timing may be perfected, and *and's* and *uh's* as well as unclear technical points will become instantly apparent to the speaker, so that he may shape a perfect talk.

Summary

After this review of the field a tentative coefficient of information transfer may be formulated as a stimulus to discussion and as an approach to the quantitative evaluation of information transfer. The factors involved are

1. Minimum number of words that must be read (or listened to) to perceive the idea.
2. Number of illustrations used.
3. Flesch reading-ease score.
4. Flesch human-interest score.
5. Complexity of illustrations.
6. Ease of associating illustrations and text.
7. Degree of organization of material presented.

A coefficient may be formulated as follows:

C.I.T. =

$$\frac{(\text{No. Illus.})(\text{Reading Ease})(\text{Human Interest}) \left(\frac{\text{Assoc. of Illus.-Text}}{\text{Complexity of Illustrations}} \right) (\text{Organization})}{\left(\frac{\text{Min. No. of Words Necessary to Read}}{\text{Complexity of Illustrations}} \right)}$$

A better engineered tomorrow will depend on better communication among scientists and engineers and between these groups and society. What is your coefficient of information transfer?

Literature Cited

1. Anonymous, *Readers Digest*, **53**, No. 327, 62 (July 1949).
2. Baker, M. H., *Chem. Eng. News*, **28**, No. 25, 2079 (June 19, 1950).
3. Demmerle, R. L., *Chem. Eng.*, **57**, No. 3, 181-2 (1950).

4. Flesch, R., "The Art of Readable Writing," Harper and Bros., New York (1949).

5. Glover, J. G., "Business Operational Research and Reports," American Book Co., New York (1949).

6. Horn, J., *Machine Design*, **21**, No. 10, 108 (Oct. 1949).

7. Jones, B. A., "Make Slides Worth While," paper presented before meeting of S.A.E., Detroit (Jan. 1952).

8. Nichols, W. T., *Chem. Eng. News*, **26**, No. 8, 602 (March 1, 1948).

9. Seinwerth, H. W., *Chem. Eng.*, **58**, No. 6, 232, 234, 236, 239 (July 1951); No. 12, 290, 292, 294 (Dec. 1951).



Fig. 9. A model gets the story across.

Socony-Vacuum Oil Co.

PLASTICS EQUIPMENT REFERENCE SHEET

RAYMOND B. SEYMOUR and ROBERT H. STEINER

The Atlas Mineral Products Co., Mertztown, Pa.

PLASTICIZED VINYL RESINS: Polymers in which vinyl chloride is the major component are available as lacquers, plastisols, plastigels, organosols, tubing and sheet.

APPLICATION AND REMARKS: Lacquers can be applied by brushing or spraying to properly prepared surfaces. Most commercial products can be applied directly to concrete, wood or sandblasted steel but require special corrosion inhibiting primers for non-sandblasted steel surfaces. A minimum of three coats is recommended for protection against fumes, vapors or occasional splash and spillage of corrosive materials. Thin organic coatings are not recommended for continuous immersion in corrosive media but may be used to prevent metallic contamination of noncorrosive liquids. Plastisols (dispersions of vinyl resins in liquid plasticizers) are applied as heavy

ier coatings by brushing or dipping, usually on irregularly shaped equipment such as plating racks, dipping baskets, etc.; plastigels (plastisols with a gelling agent), can be troweled onto flat surfaces to form a fairly heavy coating. Both of these forms require careful surface preparation, special primers and baking at 325-375° F. Plasticized vinyl sheet is available in thicknesses from 1/16 in. to 1/4 in., the most common thickness being 3/32 in. Sheet stock is used as gasket material and linings. The latter are field- or shop-applied over primed sandblasted steel surfaces by trained applicators using specially developed techniques.

CHEMICAL COMPOSITION: Comparatively high molecular weight polyvinyl chloride polymers or copolymers

of vinyl chloride with minor amounts (3-15%) of vinyl acetate, vinylidene chloride, styrene, acrylonitrile or other monomers with varying amounts (10-50%) of a wide variety of plasticizers, such as phthalate or phosphate esters together with small amounts of stabilizers and pigments. Fillers may also be added, but their use is comparatively rare in chemically resistant vinyl compositions. The extremely wide latitude used in compounding results in considerable differences in chemical resistance and physical properties. Thus, it is difficult to generalize on the physical and chemical properties of plasticized vinyl resins. Data given for a typical vinyl resin may be used as a guide prior to practical tests.

TEMPERATURE LIMITATIONS: Since vinyl resins are thermoplastic, they are not recommended for protection against corrosives at temperatures above 150° F.

A TYPICAL PLASTICIZED VINYL SHEET MECHANICAL AND PHYSICAL PROPERTIES

Tensile strength, lb./sq.in. @ 77° F.	2500
Elongation % at break	350
Hardness, Type A Shore Durometer	80
Specific gravity	1.3
Specific heat (B.t.u./lb.) (° F.)	0.4
Brittle point (° F.)	-25
Water absorption %	0.2

CHEMICAL RESISTANCE

	C	H
ACIDS		
Acetic, 10%	F	N
Acetic, glacial	N	N
Benzene sulfonic	E	E
Benzoic	E	E
Boric	E	E
Butyric	G	F
Chloroacetic	F	N
Chromic, 10%	E	G
Chromic, 50%	E	F
Citric	E	F
Fatty acids (C ₈ and up)	E	F
Fluosilicic	E	F
Formic	E	E
Hydrobromic	E	E
Hydrochloric	E	E
Hydrocyanic	E	E
Hydrofluoric	E	E
Hypochlorous	E	E
Lactic	E	E
Maleic	G	E
Nitric, 5%	E	F
Nitric, 20%	G	F
Nitric, 40%	E	F
Oleic	E	E
Oxalic	E	E
Perchloric	E	E
Phosphoric	E	E
Picric	P	E
Stearic	E	F
Sulfuric, 50%	E	E
Sulfuric, 70%	E	G
Sulfuric, 93%	E	N
Oleum	E	N
Mixed acids, 28% HNO ₃ , 55% H ₂ SO ₄	G	P
ALKALIES		
Ammonium hydroxide	E	E
Calcium hydroxide	E	E
Potassium hydroxide	E	E
Sodium hydroxide	E	E
ACID SALTS		
Alum	E	E

	C	H
AMMONIUM, Cl, NO₃, SO₄		
Copper Cl, SO ₄	E	E
Ferric Cl, SO ₄	E	E
Nickel Cl, SO ₄	E	E
Stannic Cl	E	E
Zinc Cl, SO ₄	E	E
ALKALINE SALTS		
Barium sulfide	E	E
Sodium bicarbonate	E	E
Sodium carbonate	E	E
Sodium sulfide	E	E
Tri-sodium phosphate	E	E
NEUTRAL SALTS		
Calcium chloride	E	E
Calcium sulfate	E	E
Magnesium Cl, sulfate	E	E
Potassium Cl, NO ₃ , SO ₄	E	E
Sodium Cl, NO ₃ , SO ₄	E	E
GASES		
Chlorine wet	E	E
Chlorine dry	E	F
Sulfur dioxide wet	E	E
Sulfur dioxide dry	E	E
Hydrogen sulfide	E	E
ORGANIC MATERIALS		
Acetone	N	N
Alcohols, methyl, ethyl	E	E
Aniline	N	N
Benzene	P	N
CCl ₄	N	N
Chloroform	N	N
Ethyl acetate	N	N
Ethylene chloride	N	N
Formaldehyde, 37%	E	E
Gasoline	E	F
Phenol	N	N

	C	H
Refinery crudes		
Trichloroethylene	N	N
PAPER MILL APPLICATIONS		
Kraft liquor	E	E
Black liquor	E	E
Green liquor	E	E
White liquor	E	E
Sulfite liquor	E	E
Chlorite bleach	E	E
Alum	E	E
PHOTOGRAPHIC INDUSTRY		
Developers	E	G
Silver nitrate	E	G
General use	E	E
FERTILIZER INDUSTRY		
General use	E	E
STEEL INDUSTRY		
Sulfuric acid pickling	E	E
Hydrochloric acid	E	E
H ₂ SO ₄ -HNO ₃ pickling	E	E
TEXTILE INDUSTRY		
General use	E	E
Hypochlorite bleach	E	G
FOOD INDUSTRY		
General use	E	E
Breweries	E	E
Dairies	E	E
MISCELLANEOUS INDUSTRIES		
Plating	E	E
Petroleum	E	E
Tanning	E	E
Oil and soap	E	E
Water and sewer	E	E

RATINGS:
E—No attack.
G—Appreciably no attack.
F—Some attack but usable in some instances.
P—Attacked—not recommended.

N—Rapidly attacked.
C—Cold—75° F.
H—Hot—150° F.

No. 22



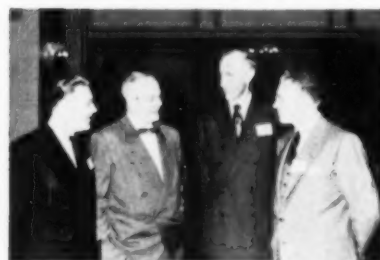
Left to right: T. S. Mertes and H. B. Rhodes, both of Sun Oil Co., F. S. McCarthy, Canadian Industries, Ltd., Richard Stephenson, Carbide & Carbon Chemicals Co., and Seymour Calvert, Univ. of Michigan, all authors of the papers in Technical Session No. 4.



Some authors in the Chemical Engineering Processes Symposium; Left to right: T. T. Anderson, Aluminum Co. of Canada, Ltd., J. M. Humphrys, Canadian Industries, Ltd., Joseph F. Skelly, M. W. Kellogg Co., and R. Bolduc, Aluminum Co. of Canada, Ltd.



C. J. Quigley, Johns Hopkins Univ., K. F. Gordon, M.I.T., Prof. Charles R. Wilke, Univ. of California, C. L. Ruby, Princeton Univ., and Prof. B. L. Harris, Johns Hopkins Univ.



Speakers of Communications Symposium; A. J. Johnson, Shell Development Co., G. Brighouse, Occidental College, C. N. Sjogren, C. F. Braun & Co., Dwayne Orton, director of education, International Business Machines Corp.

First Joint Conference with Canadians Held in Toronto

Variety was the keynote of the recent Toronto Joint Conference of the American Institute of Chemical Engineers and the Chemical Engineering Division of the Chemical Institute of Canada. The weather was variable, attendance was about equally divided between Canadians and Staters, and the technical programs covered a vast number of items ranging from how successfully to communicate with technical people, to heavily theoretical papers which, by their very nature, could be communicated only to a few.

The weather provided one of the interesting varieties for the American chemical engineers. Spring, which had been lush and well advanced when the Institute met just a short time before in Biloxi, Miss., had not quite reached the capital city of Ontario, and a mixture of thunderstorms, cold weather, and rain, then a few fine days kept the weather in line with the changing aspects of the conference itself. Altogether, 524 chemical engineers checked into the Royal York, the headquarters hotel, to participate in a twenty-two paper program.

Luncheons and dinners were featured with speakers, a touch which has been missing from recent Institute meetings, and provided several insights into aspects other than chemical engineering.

Dinner on Tuesday evening had Dr. H. L. Keenleyside, director, United Nations Technical Assistance Program, speaking on the task which the United Nations has undertaken in bringing modern science to less-advanced nations. Keenleyside commented that "the inhabitants of the Nile and Euphrates are living in practically the same manner as their ancestors lived three thousand years ago, but that for many backward peoples there have been more changes in the last two hundred years than in the previous ten thousand as far as their living conditions are concerned."

Keenleyside, during the talk, sided with the optimistic about world conditions in general, remarking that "appalling as the inhumanity of the recent past has been, it is false to argue that we have made no progress. Never before in history have so many groups given the affirmative answer to the question 'Am

I my brother's keeper?' The challenge to the United Nations," he said, "besides the threat of war, is that a large proportion of the human population suffers from illness, ignorance, and hunger, and cannot afford decent clothing and housing." He estimated that two thirds of the population of the world has an income less than \$100 a year. "The problem today facing civilized nations," he added, "is—what can we do about it?"

Touching on the problem of aggression in the world, Dr. Keenleyside asserted that we must continue to work for effective atom control, and that the free nations of the world must defend individual rights and freedom wherever they are found. "There is no substitute for due process of law, and we, as a nation, cannot long survive in freedom if four out of five people in the world are united in despotism."

The part that technology is playing in bringing about better living standards was touched upon by Keenleyside. The United Nations is tapping technical resources in many nations, including the United States, and has helped in many aspects.

Dr. Keenleyside mentioned the technical development in the West Indies, where one of the islands has a natural hot-water spring, and that through help given by the United Nations Technical Assistance Program the natural hot water is now being used to generate power.

In the Far East, Western technicians have helped Ceylon to build a salt-water evaporation plant for a supply of salt. They are helping India to reorganize the largest fertilizer plant in the world and they have aided other countries in the building of alcohol plants in an effort to obtain liquid fuels for power.

One of the challenges facing United Nations was, he said, in Jordan, where there is a variety of small plants located in what is probably the most fertile country in the world. An effort is now being made to develop all the resources of that country.

Another example he gave of how Western technology can help other nations in the Western Hemisphere, was the success in getting Brazilian pigs to eat surplus coffee. Through the help



R. L. Pigford and R. E. Emmert, Univ. of Delaware. Mr. Emmert won the award for the best presented paper.

Left: To illustrate the talk on scale models, an example was set up outside the meeting room.



At the banquet on Tuesday night: Dr. A. E. Berry, director of the C.I.C., J.V.N. Dorr, Dorr Co., and Dr. R. R. McLaughlin, Univ. Toronto.



Prof. Brymer Williams, Univ. of Michigan, B. B. Kuist, Fluor Corp., Prof. J. Louis York, Univ. of Michigan, head of Paper Judging Committee.



Mr. and Mrs. H. R. Lyle Streight. Mr. Streight, who is with the Canadian Industries, Ltd., is the proponent of the idea of a joint meeting between Canadian and American chemical engineers.



J. Watson Bain, Honorary Chairman, Toronto meeting, and Dr. Sidney Smith, president, Univ. of Toronto. Both spoke at the Tuesday evening banquet.



President of the A.I.Ch.E., W. T. Nichols, with the Mayor of Toronto, Allen A. Lamport, and Adolph Monsaroff, chairman, Executive Committee in charge of Toronto meeting.



Mrs. H. N. Potter, Mrs. J. C. Honey, Mrs. W. A. James, of the Ladies' Committee. Mrs. J. H. Bigelow, also of the committee, was not present when the photo was taken.

of an American expert, a food stimulant, called a pig catnip, was made and the coffee is now quite palatable to the Brazilian pigs.

The Monday luncheon had as its speaker, Robert H. Saunders, chairman of the Hydro Electric Power Commission of Ontario, who gave the chemical engineers a rapid summary of the electrical industry of Canada. One of the main uses of electricity in Canada, Mr. Saunders said, is the production of alumina, since Canada is the world's largest exporter of this commodity. He stated that the new aluminum plant at Kitimat, 400 miles north of Vancouver, will have the largest single generating plant ever built, supplying as much as 2,240,000 hp. if necessary, to operate the Kitimat smelter. The rate of growth of aluminum production in Canada, he traced as jumping from 498,000 tons in 1952 to more than 600,000 tons by 1955.

One of the great projects in Canada yet to be achieved, and moving steadily towards realization, is the tapping of the St. Lawrence River power. The amount of power that could be developed through the utilization of the St. Lawrence River, according to Mr. Saunders, is equivalent to 5,244,000 tons of coal a year. In support of his plea for development of the river, he quoted the Counsel of the Federal Power Commission as saying that the United States is losing approximately \$3,361,000 for each month that the St. Lawrence remains undeveloped. The dramatic import of the power to Canada, was effectively illustrated by Saunders when he stated that it was possible to develop an amount of electricity out of the projected hydroelectric developments equivalent to 900,000 kw. which would be, he said, equivalent to the December peaks of eleven major Ontario cities, and more than double the peak load of the city of Toronto.

In addition to the St. Lawrence power project, Mr. Saunders touched on another vital technical development, the St. Lawrence Seaway. The key position of United States cooperation in this project was illustrated when Saunders reiterated the determination of Canada to build the seaway alone, claiming that Canada was not asking for assistance, but rather asking for cooperation. However, at present the seaway is held up, he said, because of the power development, which in turn is being held up because of problems within the United States.

The third luncheon speaker, Carl F. Braun, president of C. F. Braun & Co., Alhambra, Calif., hammered away at the lack of easy communication between engineers and accountants. Mr. Braun termed the lack of effective communications between industry and accountants a blind spot and one that had been

strangely overlooked. According to Mr. Braun, the most important thing in accounting figures is the accounting significance of the figures. "If an accountant starts with data and carries his computation out to six places, it has no meaning," said Mr. Braun. "It is only the first three that have any significance. For instance, management may be told that we spent \$283,000 on some expense item. The figure \$280,000 is all they'll remember."

One other foible of accounting pointed out by Mr. Braun, is the fact that money values are not the most interesting figure. Hours are also quite important to management and the accountant, if left alone, will fail to give management this most significant figure.

The tradition by which the accountant is bound was decried by Mr. Braun, stating that the accountant "was working with an obsolete tool—a tool designed originally for money-lenders, traders, and merchants, a tool concerned with who owes what to whom." Mr. Braun said that his company sensed the shortcomings of conventional accounting, and finally decided it was a mistake to leave accounting to accountants. Consequently, his company's management—engineers and operators—got deeply into the accounting problem and

decided what they wanted in the way of information.

Braun said that the primary purpose of accounting is as a tool for the men who operate the enterprise. It must also help to run the business, he said, and accounting that merely records, is no accounting at all. The accountants in his company, he said, must first tell the leaders, by a budget, the expected operation and the expected results, and then later, at proper intervals, the accounting department must tell the leaders how their performance is comparing with the goals. Accounting, he said, must be concerned with definite goals of performance and should keep its eye on these goals.

Braun also hit out against the jargon of accounting and called for the accounting field to learn to use the language of the people. Words singled out by Braun as being unnecessary, were: invoices, revenue, remittance advice, impress fund, deferred pay, deferred taxes, reserve, debit, and credit. He called upon the accountants to get rid of jargon and stamp out reverse English and two-faced English. He called on accountants to "study semantics and be concerned with the meaning and import of words." Unless they do," he said, "they will not get accuracy, reliability, and objective think-

ing into their work; they will not do a good job either of organizing information or communicating it."

A description of the manufacture of nitroglycerine by the Biazzi continuous process was given during the meeting by H. J. Klassen and J. M. Humphreys of Canadian Industries, Ltd. The plant of the company at Calgary is designed to produce 2,500 lb. of nitroglycerine an hour, and the process was selected over the conventional batch process not only because of the advantage of continuous operation, but because of greater safety. In the process, glycerine and ethylene glycol are mixed in flow, and enter a nitration building as a single stream. Both the acid, glycerine and glycol are introduced from the top of the nitrator along the shaft of a stirrer. They are drawn toward the bottom of the impeller, mixed, and thrown outward by the centrifugal force to the walls. The action is extremely rapid and the emulsion of nitroglycerine and spent acid rises in a spiral movement around the cooling coils, and part of it leaves the nitrator by an overflow, while the remainder is again drawn down to the center.

The advantages of the Biazzi
(Continued on page 26)



Henry F. Nolting, Standard Oil Co. of Indiana.



Speaker, H. G. Joseph, The Ontario Paper Co., Ltd., presents first paper.



Prof. R. R. McLaughlin, was chairman of first technical session.



Dr. H. L. Keenleyside spoke at the banquet on Tuesday evening.



W. M. Karn, Electric Reduction Sales Co., Ltd., and chairman of Hotel and Entertainment Committee.



C. F. Braun of C. F. Braun & Co. told engineers that accountants needed simpler language.



G. A. Purdy, Imperial Oil Co., who was chairman of the Public Relations Committee, Toronto meeting.



Garnett Page, General Manager and Secretary, Chemical Institute of Canada.

BROWN TO SUCCEED DELONG AS TREASURER



G. G. Brown



C. R. DeLong

George Granger Brown, President of the American Institute of Chemical Engineers in 1944 and dean of the College of Engineering, University of Michigan, Ann Arbor, was appointed by Council, Treasurer of the Institute, effective June 1. He replaces C. R. DeLong. Always a participant in the affairs of the Institute, Dr. Brown served as its Director in 1940-42 and since 1951 as chairman of the Chemical Education and Accrediting Committee. He won in 1939 Institute's William H. Walker Award. In 1950 Dr. Brown was named director, U. S. Atomic Energy Commission division of engineering, and early in the current year he was elected a director of the Nash-Kelvinator Corp.

The former Treasurer, C. R. DeLong, vice-president, North American Solvay, Inc., and the Solvay American Corp., was A.I.Ch.E. Treasurer for the past sixteen years. A B.S. in chemical engineering, Ohio State University, Mr. DeLong has been identified with many endeavors such as the Amusol Corp., New York; Federal Phosphorus Co., Birmingham, Ala.; U. S. Tariff Commission; and as a consulting chemical engineer, New York. Last December, at the annual meeting in Cleveland, Mr. DeLong announced his desire to retire as Institute Treasurer and asked Council to appoint a successor. At that time, he said, he regarded his office as "not only a distinct honor, but also a great pleasure . . ."

NEW BOILER DESIGNED FOR COPPER SMELTER

A specially designed boiler will facilitate the recovery of copper at the White Pine copper smelter, near Ontonagon, Mich., in one of the richest undeveloped deposits in North America, according to the Babcock & Wilcox Co., designers and builders of the boiler. It will utilize what would otherwise be waste heat from a copper reverberatory furnace to supply steam to a turbo-generator to furnish power for the projected development. The ore mineral is mainly chal-

cocite, a cuprous sulfide (Cu_2S), and total ore reserves amount to 309 million tons averaging 21.3 lb. of copper/ton, according to the Copper Range Co., developers of the site.

The boiler, Babcock and Wilcox engineers stated, will be about six stories high and is to be in line with and following the reverberatory furnace in which the copper ore is melted. The gases or products of combustion, heavily laden with slag particles and dust, leave the reverberatory furnace at a rate of approximately 143,000 lb./hour at a temperature of 2600° F., entering first the waste-heat boiler furnace, then passing through the superheater and convection center of the boiler. The hot slag particles will fuse on any surface with which they come in contact, especially if the furnace is hot. To cope with this problem, the waste-heat boiler was specially designed with tube-to-tube water-cooled wall radiation chamber, widely spaced platten-filled chamber, superheater chamber, and a cross-flow convection boiler section.

The heat absorption of the water-cooled furnace walls and the water-cooled platens reduces the temperature of the incoming gases 400 to 500° F. before they enter the superheater chamber. Thus the suspended slag particles are cooled to a dry ash, which drops into the hoppers under the boiler, from which it is returned to the reverberatory furnace for retreatment to reclaim the copper.

Using waste heat from the reverberatory furnace, instead of fuel, for the generation of steam, the waste-heat boiler recovers about 50% of heat in the fuel originally supplied to the reverberatory furnace.

The boiler is designed to generate steam at 885 lb./sq.in. at a temperature of 920° F. at the superheater outlet. The steam generated is used not only in the power plant, but a portion is used to preheat combustion air, by means of steam air heaters, for the furnace.

At such times as the reverberatory furnace may be shut down for repairs, the boiler, by a special arrangement, can be fired with pulverized coal.

NEW ISOTOPE CATALOGUE AVAILABLE

A new catalogue of isotopes, both radioactive and stable, produced by Oak Ridge National Laboratory is now available, according to an announcement by the laboratory. More than 100 radioactive and 175 stable isotopes are listed, together with prices and descriptive material. The catalogue replaces the edition published by A.E.C. in March, 1951, and may be obtained for \$1.00 from Carbide and Carbon Chemicals

Co., Oak Ridge National Laboratory, Radioisotope Sales Department, Post Office Box P, Oak Ridge, Tenn.

ZEISBERG AWARD WINNERS

This year's winners of the F. C. Zeisberg Memorial Award for excellence in report writing were announced May 12.



John M. Roblin

tries."

John M. Roblin, a senior chemical engineering student at Princeton University, was named first-place winner of the Zeisberg Award. Angelo DiGiacomo, a senior at Drexel Institute of Technology, won the second prize. The third prize was awarded to Erwin G. Meeh, Jr., of Lehigh University.

The occasion was the dinner meeting of the Philadelphia - Wilmington Section of A.I.Ch.E. at the Penn-Sheraton Hotel, Philadelphia, held at the conclusion of an all-day technical meeting on "Chemical Engineering in the Process Industries."



Angelo DiGiacomo

G. Meeh, Jr., of



Erwin G. Meeh, Jr.

of A.I.Ch.E. (1938), an engineer of the Du Pont Co., and active in encouraging good report writing by young engineers.

The Zeisberg Award is presented annually to the students submitting the best written reports in connection with their regular academic studies and chemical engineering laboratory experiments. It is offered in memory of the late Fred C. Zeisberg, President of the Du Pont Co., and active in encouraging good report writing by young engineers.

EXPANSION OF AMMONIA PLANT IN MISSISSIPPI

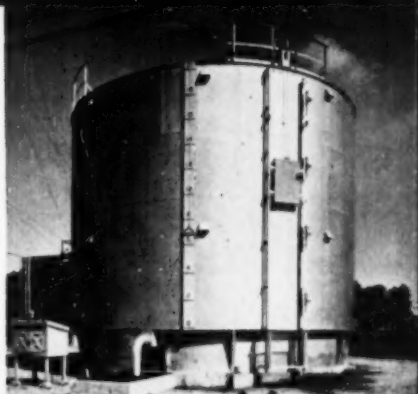
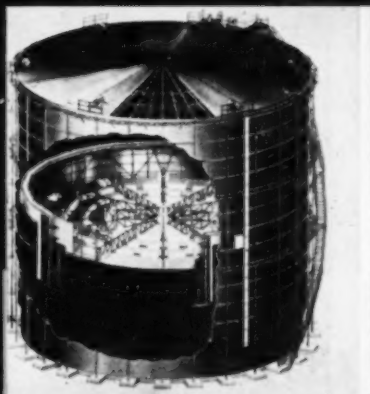
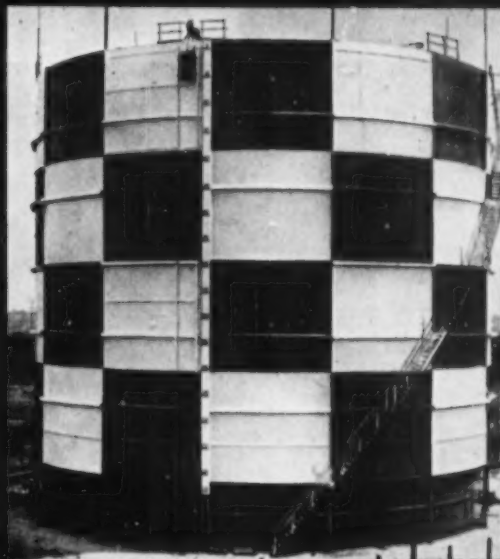
Mississippi Chemical Corp. has announced an increase in the capacity of its ammonia plant from 120 to 180 tons/day. The new construction, to be undertaken by the Girdler Corp., Louisville, Ky., will cost over \$2 million and is expected to be completed late in 1953.

(More News on page 25)

simple! proved in use!

Wiggins Gasholder

BY GENERAL AMERICAN

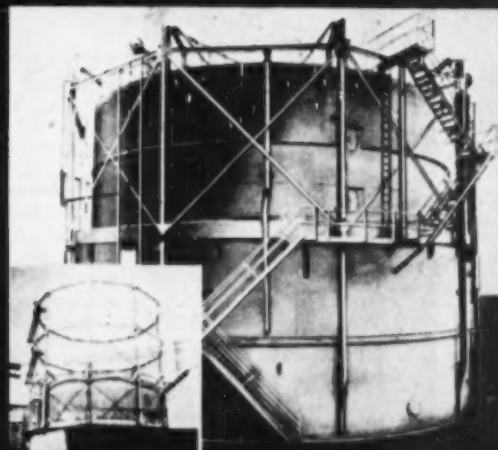
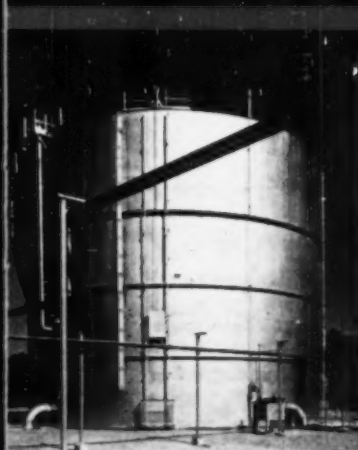


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NO OPERATING COSTS
NO MAINTENANCE
PROBLEMS**



GENERAL AMERICAN



**TRANSPORTATION
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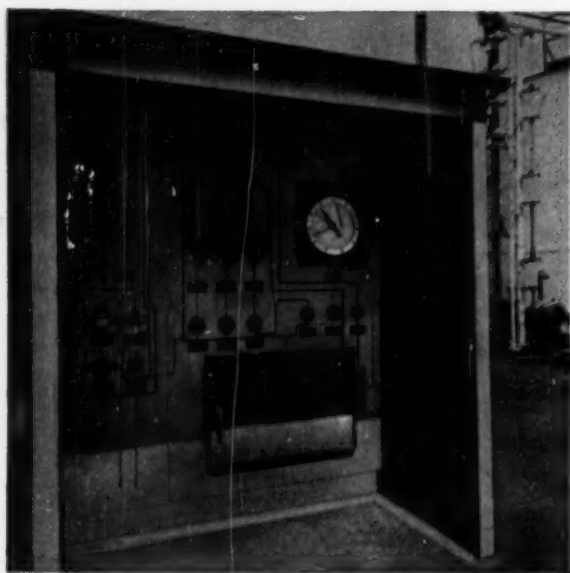
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you plan any gasholder construction.*



infra-red analysis tells how much of a selected component exists in gas mixtures. Here, continuous analysis recorded by an **ElectroniK** potentiometer on a refinery's graphic panel is used for actual process control.



mass spectrometry separates materials on the basis of their different molecular weights . . . finds what constituents are present in what quantity. Above is a "package" mass spectrometer in which an **ElectroniK** instrument records test data.




gas analyzer, operating on the thermal conductivity principle, combines an **ElectroniK** recorder, analysis cell and accessories in a single panel assembly.

New concepts *utilize*

These are some of the manufacturers who
use **ElectroniK** instruments in their analyzers

Products of the companies checked are illustrated on these pages

- | | |
|--------------------------------------|----------------------------------|
| Applied Research Laboratories | Mine Safety Appliances Co. |
| Baird Associates | North American Philips Co., Inc. |
| Bausch and Lomb | Perkin-Elmer Corp. |
| Beckman Instruments, Inc. | ✓ Podbielniak, Inc. |
| Consolidated Engineering Corporation | Precision Scientific Co. |
| ✓ Davis Emergency Equipment Co. | E. H. Sargent & Co. |
| ✓ General Electric Co. | Tracer Laboratories |
| Jarell-Ash | ✓ Applied Physics Corp. |



robotized distillation apparatus determines composition of hydrocarbon mixtures in minutes instead of hours. The temperature versus volume-distilled curve drawn by the *ElectroniK* potentiometer needs no replotting for computing analysis.

of process control

ElectroniK instruments

FROM the analytical laboratory comes a new concept of industrial process control, based directly on the desired chemical or physical characteristics of the product.

Continuous analyzers now make it possible to measure composition of gases and liquids accurately and automatically . . . to record this information . . . even to actuate automatic controls. Instead of temperature, pressure and flow, these new systems deal in terms of refractive index, density, ultraviolet and infrared spectra, radiation intensity and absorption.

An essential component of all these systems is automatic recording. To fill this critical function, leading manufacturers of automatic analyzers choose *ElectroniK* instruments. They choose them

for their exceptional accuracy, that exploits fully the inherent precision of the new measuring techniques. They choose them, too, for sensitivity that records every essential change in readily readable detail. And they prefer *ElectroniK* recorders for their simple, rugged design that guarantees dependable service under any industrial conditions.

Your local Honeywell engineering representative will be glad to discuss the role of *ElectroniK* instruments in product-analysis systems . . . or in any conventional process control. Call him today . . . he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO.,
Industrial Division, 4427 Wayne Ave., Philadelphia
44, Pa.

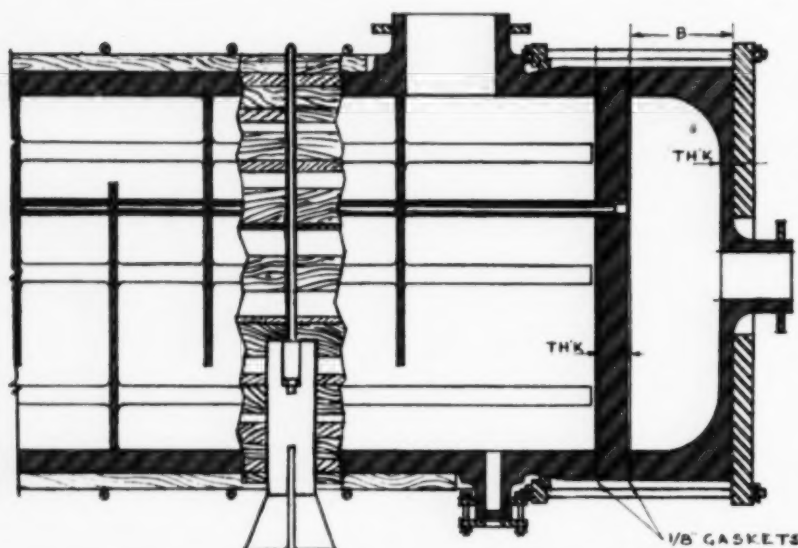
● REFERENCE DATA: Write for Bulletin 15-14, "Instruments Accelerate Research."



MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS

First in Controls

Standard Pressure HAVEG Heat Exchangers . . .



HAVEG is a rigid moldable material (not a coating or lining) made by mixing acid-digested asbestos with special synthetic resins. Thousands of Haveg vessels, molded under heat and pressure at the Marshallton, Delaware factory, have outstanding service records, with excellent and uniform resistance to corrosion. Now Haveg is available for difficult, high temperature and pressure heat exchange applications. The use of corrosion-resistant Haveg makes possible the passage of corrosive liquids and gas either through the tubes or shell. Larger, longer-lived heat exchangers, coolers, towers can be rapidly molded and fabricated. Prices are competitive.

INSIDE-OUTSIDE CORROSION?

Resistant to practically all acids, chlorine, salts, many solvents . . . even at boiling temperatures . . . HAVEG gives complete protection on all surfaces of the heat exchanger. Because of chemical inertness and low heat conductivity Haveg is used in end tube sheets—fixed and floating; as the strong outer shell, for heads and baffles. Haveg is a non-conductor; electrolytic corrosion is no problem.

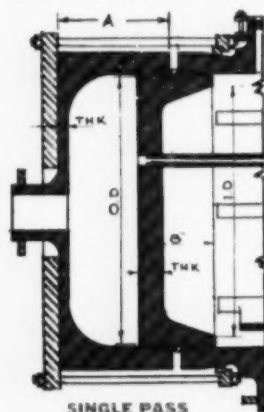
HIGHER HEATS AND PRESSURES

Haveg is resistant to thermal shock and can be used continuously up to 265° F. The pressure range of the new Standard Haveg Heat Exchangers is from 50 to 75 lbs., with a wide safety margin.

SHELL I.D.	SHELL O.D.	SHELL THK.	WORKING PRESSURE	NO. OF TUBES	TOTAL EFFECTIVE TUBE AREA SQ. FT.		FLOATING TUBE SHEET			FIELD TUBE SHEET		MAJOR BAFFLES		HEADS		
					INSIDE	OUTSIDE	I.D.	O.D.	THK.	THK.	THK.	LIQUID	STEAM	THK.	A	B
13 1/2"	18 3/4"	1 1/2"	72	33	6.5	92	10 1/2"	12 1/2"	2 1/2"	2 1/2"	2 1/2"	2 1/2"	4	3 1/4"	7	3
15 1/2"	20 3/4"	1 1/2"	72	48	9.4	134	12 1/2"	14 1/2"	2 1/2"	2 1/2"	2 1/2"	4	4	3 1/4"	7	3
17 1/2"	22 3/4"	1 1/2"	72	64	12.5	179	14 1/2"	16 1/2"	2 1/2"	2 1/2"	2 1/2"	4	4	3 1/4"	8	4
19 1/2"	24 3/4"	1 1/2"	72	81	15.9	227	16 1/2"	18 1/2"	2 1/2"	2 1/2"	2 1/2"	4	4	3 1/4"	8	4
21 1/2"	26 3/4"	1 1/2"	70	106	20.8	297	18 1/2"	20 1/2"	2 1/2"	2 1/2"	2 1/2"	4	4	3 1/4"	10	5
23 1/2"	28 3/4"	1 1/2"	65	134	26.3	375	20 1/2"	22 1/2"	2 1/2"	2 1/2"	2 1/2"	4	4	3 1/4"	10	5
25 1/2"	30 3/4"	1 1/2"	60	162	31.8	453	22 1/2"	24 1/2"	2 1/2"	2 1/2"	2 1/2"	4	4	3 1/4"	12	10
27 1/2"	32 3/4"	1 1/2"	55	192	37.6	537	24 1/2"	26 1/2"	2 1/2"	2 1/2"	2 1/2"	4	4	1"	12	10
29 1/2"	34 3/4"	1 1/2"	50	235	46.1	658	26 1/2"	28 1/2"	2 1/2"	2 1/2"	2 1/2"	4	4	1"	12	10

*WORKING PRESSURE: MAX. OPERATING PRESSURE TUBES OR SHELL SIDE P.S.I.G.

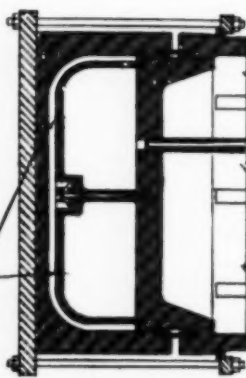
MAX. STEAM PRESSURE 25 P.S.I.G.



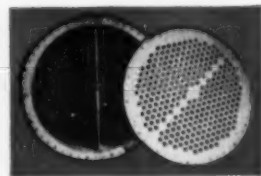
SINGLE PASS

A Haveg Heat Exchanger offers a variety of floating head types. Standard single pass head (left) is interchangeable with multi-pass head (Detail 2).

Note pressure neutralizing holes: Haveg machines to close tolerances for a tight fit.



MULTI-PASS BAFFLE
DETAIL #2



Coolers—Low pressure chlorine coolers may be supplied up to 10' diameter. All parts are replaceable; any kind of tubes or packing can be used. Multi-pass head features removable baffle. Because Haveg is molded, openings can be made any size or location. Usually steel water heads are supplied with gas passing through the shell, water passing through the tubes. Water heads may be removed without dismantling the Haveg Cooler; replacement of tubes is easily made.

PUMPS TANKS PIPE



CORROSION RESISTANT EQUIPMENT
FACTORY: MARSHALLTON, DELAWARE

Backed by twenty years of manufacturing experience, Haveg already has the molds . . . up to 10' diameter . . . for building any size or style low pressure heat exchanger, cooler, cylindrical tower. Standard Pressure sizes are from 13 1/4" to 29 1/4". Single or multiple pass. Special impingement plate protects tube bundle. Interchangeable end covers. Openings molded in at no extra cost; repairs or alterations in the field are easily made. Get information on new Standard Haveg Heat Exchangers, built to your prints, or cooperatively Haveg-engineered with your supplier.

Send coupon today . . . call your Haveg sales office in Atlanta, Chicago, Cincinnati, Cleveland, Detroit, Hartford, Houston, Los Angeles, Seattle, St. Louis. The Haveg Corporation, Newark, Delaware. Factory: Marshallton, Delaware. Wilmington 3-8884.

Send coupon today . . . call your Haveg sales office in Atlanta, Chicago, Cincinnati, Cleveland, Detroit, Hartford, Houston, Los Angeles, Seattle, St. Louis. The Haveg Corporation, Newark, Delaware. Factory: Marshallton, Delaware. Wilmington 3-8884.

- ☐ Send 64-page F-6 Haveg Technical Bulletin.
- ☐ Send blueprint of Standard Haveg Heat Exchangers.

We're interested in ☐ Coolers ☐ Towers.

☐ Have Haveg Sales Engineer call.

Name _____ Title _____

Company _____

Address _____

City _____ State _____

NEWS

(Continued from page 20)

NEW UREA PROCESS FOR CHEMICO

A new urea synthesis process has been announced by Chemical Construction Corp. A complete recycle process, the new development, according to E. D. Powers, president of the corporation, permits 76% conversion of ammonium carbamate to urea per pass. Excess ammonia is separated from the autoclave product as a gas, condensed without compression, and recycled by pumping. Unconverted carbamate, Mr. Powers explained, is decomposed, and the ammonia carbon dioxide gas mixture obtained therefrom is separated to recover ammonia gas for recycle. The over-all ammonia efficiency is 97%. Equipment designed for the process includes a granulator with a spraying device that permits the production of uniform spherical pellets with only minor recirculation of off-size product, Chemico's official said.

Economies of the process, according to Mr. Powers, include 70% more urea produced per pass at no increase in power consumption, minimum corrosion, simple and efficient recirculation of ammonia, and use of only about one-half the amount of carbamate.

A.S.T.M. MEETING SCHEDULED

The American Society for Testing Materials will hold its annual meeting from June 29 to July 3 at Atlantic City, N. J. Among the symposium topics will be metallic materials at low temperatures, fluorescent X-ray spectrographic analysis, porcelain enamels and ceramic coatings, and dynamic testing of soils. On June 30 there will be a lecture on micrometallurgy by Jerome Strauss, vice-president, Vanadium Corp., and on July 1 Frederick Rossini, director, A.P.I. Research Laboratory, will present "Excursion in Petroleum Chemistry."

INDUSTRY TEACHES THE TEACHERS AT DOW

The fourth A.I.Ch.E. Industry-Teaches-the-Teachers School was held on May 1 at Dow Chemical Co.'s Freeport, Texas, plant. It was attended by twenty-two faculty members from Lamar State College of Technology, Rice Institute, Texas A. & M., Tulane University, and the Universities of Houston, Oklahoma, and Texas. The all-day meeting was devoted to papers on glycol and caustic evaporation by Dow engineers V. A. Klein, E. E. Ludwig, A. F. Shorkey, and R. H. Smith, followed by a plant-inspection tour and a general discussion period.

(More News on page 28)

Garlock "O"-Ring Seals FOR ROTATING PUMP SHAFTS



A Sleeve Drive
Balanced
"O" Ring Seal

Simple in Design, Leakless in Operation

GARLOCK "O" Ring Mechanical Seals are made with a minimum of parts. This simplicity of design affords easy manufacturing adaptability of a Garlock "O" Ring Seal to withstand any liquid, whether mild, harmfully corrosive or extremely hazardous, on rotating pump shafts. The Garlock "O" Ring Balanced Seal will hold pressures up to and over 1000 p.s.i.

The "O" rings are available in "Teflon," Buna-N, Neoprene or Silicone. The metal parts contacting the liquid are available in any suitable metal.

On centrifugal pumps handling chemicals, petroleum products, edible liquids, pulp liquors, and many other liquids Garlock "O" Ring Mechanical Seals are giving outstanding service.

For positive sealing, easy installation and trouble-free service use Garlock "O" Ring Mechanical Seals on your rotating pump shafts. Write us about your sealing problems or contact your Garlock representative.

THE GARLOCK PACKING
COMPANY
PALMYRA, NEW YORK

In Canada:
The Garlock Packing Company
of Canada Ltd., Toronto, Ont.



GARLOCK

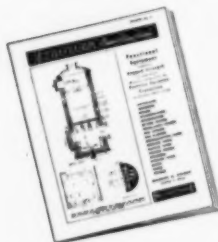
PACKINGS, GASKETS, OIL SEALS
MECHANICAL SEALS
RUBBER EXPANSION JOINTS



Pyroflex sheet lining is heat bonded to steel tank shell.



Upon installation at job site, one course of Acid-Proof Brick is set in Knight Acid-Proof Cement.



Send for illustrated Bulletin No. 2, "Pyroflex Constructions."

The acid storage tank above is "OK FOR ACID SERVICE" because it is Pyroflex constructed. It has been lined in our plant with a corrosion-proof heat-bonded Pyroflex membrane. Upon installation at job site, one course of acid-proof brick set in Knight No. 2 Acid-Proof Cement will be installed over the Pyroflex membrane.

Although this type of lining is typical of Pyroflex constructed tanks, Pyroflex construction is not limited to any specific materials. It may include steel, Knight-Ware, Permanite, rubber, lead, glass, carbon or whatever other material is best suited to individual service conditions. Thus each Pyroflex constructed unit is individually engineered for the job it must do.

Chlorinators, drying towers, scrubbers, tanks and other types of Pyroflex constructed equipment are in wide use in the chemical and steel industries and wherever corrosion-proof equipment is required. Get the complete story — send for Bulletin No. 2, Pyroflex Constructions.

Maurice A. Knight

706 Kelly Ave., Akron 6, Ohio

Acid and Alkali-proof Chemical Equipment

TORONTO STORY

(Continued from page 19)



Norman H. Parker, turbomixer division, General American Transportation Corp., and J. Y. Oldshue, Mixing Equipment Co., and Mrs. Oldshue.

nitrator in comparison with the batch type nitrator are: 1) more efficient agitation and greater speed of circulation which avoids any local overheating and oxidation of glycerine; 2) improved heat transfer between the reactants and the cooling medium; 3) better approach to countercurrent cooling because of the regular flow of liquid along the cooling coil; 4) a smaller quantity of nitroglycerine in process. In separating the acid, the mixture flows through a separator shaped like a centrifuge, the emulsion overflowing from the nitrator entering the separator tangentially. The rotation imparted to the emulsion aids the agglomeration of the droplets of nitroglycerine. Separated nitroglycerine overflows through an outlet pipe, the spent acid is withdrawn from the bottom. Only about 110 lb. of nitroglycerine is present at any one time in the separator.



T. Weaver, The Fluor Corp., Ltd., Loren P. Scoville, Jefferson Chemical Co., and chairman of the Institute's Program Committee, with C. C. Burton of the C. F. Braun & Co.



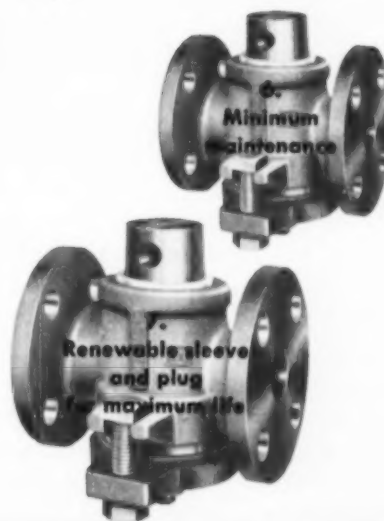
J. L. Stan, and J. P. Estabrook, both of Canadian Celanese Corp., and W. A. James of the Dearborn Chemical Co., with Mrs. James.

The one chemical service valve



seven ways better

In the past, just one or two of these advantages were enough to justify the use of a particular chemical service valve. Now DURCO engineers have designed a valve with all seven features. With several thousand in operation in the three years since they were introduced, the list of successful applications is large and varied. If you have a troublesome corrosion problem, call the DURCO representative near you, or write The Duriron Company, Inc., Dayton, Ohio.



DURCO TYPE F VALVE

corrosion resisting
with Teflon[®] Sleeve

Available in 1/4" through 7"
flanged and screwed.



*Registered trade-mark of E. I. duPont de Nemours & Co., Inc., for its tetrafluoroethylene resin.

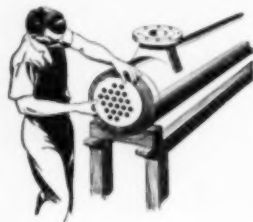
THE DURIRON COMPANY, INC., Dayton, Ohio

The single cost of TANTALUM is much less than the many costs of CORROSION...

Corrosion costs do not end simply with equipment replacement. A complete analysis must include shutdowns, lost production time, product contamination and spoilage, fume damage to buildings and associated equipment, possible injury to personnel. Compare this myriad of costs against the single outlay for Tantalum, the metal that is not merely "corrosion-resisting", but acid-proof.

If you are processing hot or strong acid solutions, if you are making a pure product in which equipment contamination or side reactions cannot be tolerated, tantalum is probably the most economical material of construction you can use. Experienced Fansteel engineers are at your service for consultation at no cost to you.

Use Tantalum with economy for most acid solutions and corrosive gases or vapors except HF, alkalis, or substances containing free SO₃.



*Ask for a copy of our free booklet
"Acid-Proof Tantalum Equipment for Chemical Operations"*

FANSTEEL METALLURGICAL CORPORATION
NORTH CHICAGO, ILLINOIS, U.S.A.

32402C

NEWS

(Continued from page 25)

STANDARD OIL (IND.) FUND FOR LIBERAL ARTS

Standard Oil Co. (Indiana) announced last month a fund of \$150,000 for use during 1953 in aiding privately financed liberal arts colleges in the fourteen midwest states where it markets directly. The funds, according to Robert E. Wilson, chairman of Standard Oil Co., are to be allocated on an equitable basis among state associations of private colleges, that have been formed for fund-raising purposes.

The company, Dr. Wilson noted, has been concerned for a number of years with the serious financial problems of liberal arts colleges. "There is real danger," he said, "of losing the enrichment of American life which has come from educating talented young people who lack financial resources. Other prospective students who could afford present tuition rates and really prefer the individuality and atmosphere of the small college are attracted away by the relatively low tuition rates still charged by the tax-supported state institutions and their excellent facilities."

BRITISH CHEMICALS TO EXHIBIT IN FALL

The first Chemical Plant Exhibition to be held in Great Britain since World War II will be presented from September 3 to 17, 1953, at Olympia, London, in connection with the Engineering, Marine and Welding Exhibition.

Sponsored by the British Chemical Plant Manufacturers' Association, exhibits will be presented by process plant designers and contractors; makers of plants for performing unit operations; and makers of ancillary equipment such as instruments, valves, pumps, packings, and joinings. In addition, a comprehensive range of engineering equipment will be shown by other sections of the exhibition.

NEW ALUMINA PROCESS

A continuous electrolytic process for producing alumina from low-grade domestic ores is ready to be licensed, according to a recent announcement of the Lobeth Corp., Chicago. According to tests made on a European pilot plant, the process, its developers state, recovers 99 to 100% of all reagents used and has been operated with low-grade kaolin clay (10% alumina and 80% silica). Electrical requirements, it is stated, are less than 2 kw.hr./lb., and preliminary cost estimates indicate that 99.9% alumina can be produced for 15 to 20% less than alumina from bauxite with present processes.

(More News on page 30)

THESE FLUIDS ARE DIFFICULT TO PUMP

ACETALDEHYDE

ACETONE

FORMALDEHYDE

FREON

MERCAPTANS

MERCURY

MOLTEN METALS

NAPHTHALENE (Molten)

NITRIC ACID

PHOSPHORIC ACID

SODIUM CYANIDE

SULFUR DIOXIDE

TRINITROCHLOROBENZENE

VINYLDENE CHLORIDE

CHLOROSULFONIC ACID

CHROMIC ACID

HYDROBROMIC ACID

NITRIC ACID

OLEUM

OXALIC ACID

PROPIONIC ACID

SULFURIC ACID

IODINE

BENZOLCHLORIDE

BENZOTRICHLORIDE

LIQUID BROMINE

CHLORACETIC ACID

DILUTE ACIDS

ALUMINUM SULFATE

DIATOMACEOUS

EARTH SLURRY

FERRIC SULFATE

SODIUM HYPOCHLORITE

SALT SOLUTIONS

SODIUM SILICOFLUORIDE

HYDROGEN PEROXIDE

HYDROCHLORIC ACID

BROMINE TRIFLUORIDE

CHLORINE

CHLORINE TRIFLUORIDE

FLUORINE GAS

HYDROFLUORIC ACID

HYDROGEN CYANIDE

HYDROGEN FLUORIDE

FLUORINE

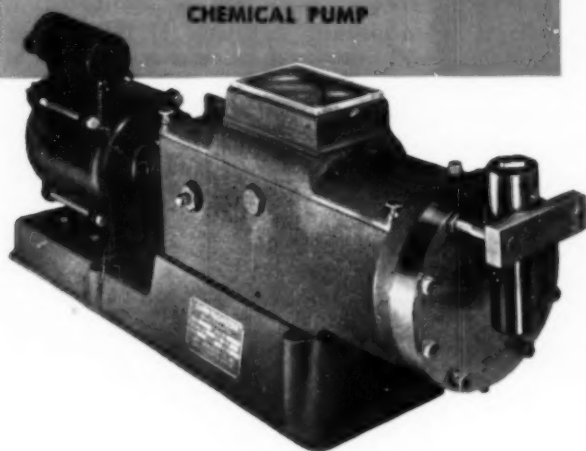
SULFUR DICHLORIDE

THEY ARE HANDLED
SUCCESSFULLY
BY THE

Lapp

PULSAFEEDER

PISTON-DIAPHRAGM CONTROLLED-VOLUME
CHEMICAL PUMP



Not competitive with any pump of more conventional design, the Lapp PULSAFEEDER is a highly specialized, precision, custom-built machine suited to a wide variety of special applications involving controlled-volume pumping of fluids.

Basic feature of Lapp PULSAFEEDER design is its combination of reciprocating piston action (to provide the accuracy of positive displacement) with an hydraulically balanced diaphragm which isolates material being pumped from working pump parts—and, of course, eliminates need for stuffing box or running seal.

Control of pumping rate is achieved at constant pumping speed; variable flow results from variation in piston stroke length—adjustable by hand-wheel, or, in Auto-Pneumatic models, by instrument air pressure responding to any instrument-measurable processing variable.

Justification for this specialized premium construction is evident in the many, and varied, applications in which Lapp PULSAFEEDER alone is able to perform satisfactorily. In fact, the economies of continuous processing, automatic proportioning, feeding and filling in many operations are possible only because of the unusual characteristics and peculiar advantages of Lapp PULSAFEEDER.

In general, use of the Lapp PULSAFEEDER is indicated for continuous (or intermittent) pumping, at accurately controlled volume, of fluids which cannot be satisfactorily exposed to conventional pistons, cylinders and stuffing box packing—because of the corrosive action of chemicals being handled and/or need for protection of product against contamination.

Lapp Bulletin 300 shows typical applications and flow charts. It describes and lists specifications of models over a wide range of capacities and special constructions. Also included is an Inquiry Data Sheet, from which we can make specific engineering recommendations for your processing requirement. For your copy write Lapp Insulator Co., Inc., Process Equipment Div., 130 Wilson St., Le Roy, N.Y.

**In production ahead of
schedule . . . thanks to**

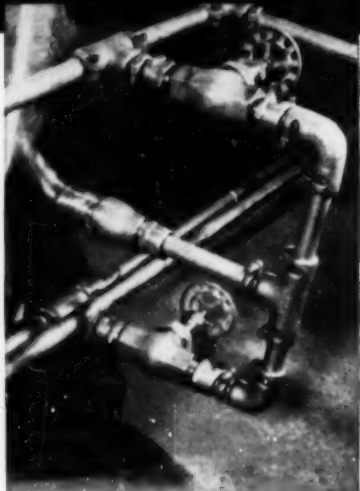
Quikupl

Says PRECISION FILM LABS
NEW YORK, N. Y.

"A quick glance at the piping layout in the print told us that we had to install about 1000 feet of stainless piping and more than 700 stainless fittings. Thinking in terms of conventional assembly methods, this meant three months of work before we could start operations."

"Just about this time, Quikupl became available. In addition to putting us in business eight weeks ahead of schedule, it sliced 40-50% off our estimated installation costs. And what's more, we now have a stainless processing line that we can tear down in a jiffy for clean-out or rearrangement."

"Cost conscious plant men will find Quikupl worth investigating."



BULLETIN Q100



Get the full story of this amazing stainless steel fitting which permits quick assembly and disassembly of stainless pipes or tubing without threading, flaring or welding.

Write for Bulletin Q100 today.

THE COOPER ALLOY
FOUNDRY CO. • HILLSIDE, NEW JERSEY

NAME _____
POSITION _____
COMPANY _____
ADDRESS _____
CITY _____ STATE _____

NEWS

(Continued from page 28)

AMERICAN FIRM MAY DEVELOP IRAQI SULFUR

An American sulfur company, according to the Iraqi government, has made a proposal to develop the sulfur area on a concession basis for 50 years on the following terms:

Expenses of development would be shared on an equal basis by the company and the Iraqi government; the company would forfeit 25% of the area exploited every 5 years until a limit is reached, not to exceed 1,000 sq.km.; the company would pay the Iraqi government a royalty of £20,000 yearly for the first 5 years; £15,000 yearly for the second 5 years; and £5,000 yearly for the subsequent years; all existing regulations and agreements in force with the Iraqi Petroleum Co. or other oil companies would apply where land utilization and expropriation of property is concerned; an Iraqi director would be appointed for every two American executives on the board.

The proposals are under consideration by the Iraqi government.

FIVE CHEM. ENGINEERING GRANTS BY EASTMAN

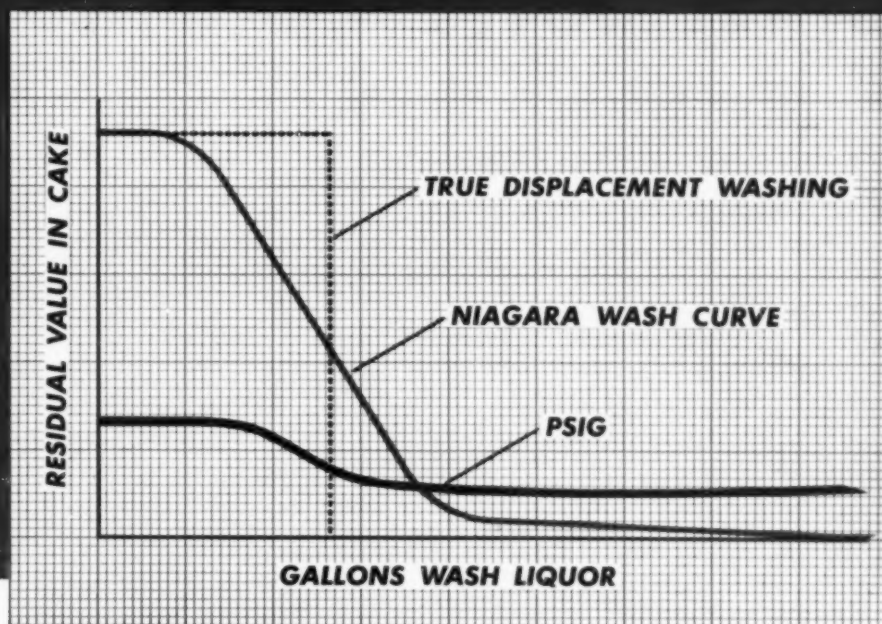
Three fellowships in chemical engineering are among the seventeen awarded to colleges and universities throughout the country by Eastman Kodak Co. for 1953-54. All for advanced study, the awards provide \$1,400 each plus an allowance for tuition and fees and a payment of \$1,000 to the university to help support the cost of research undertaken by the recipient. Selection of the recipient, who must be in the last year of study for his doctorate, is left to the institution.

Tennessee Eastman Co. has also awarded two fellowships for doctoral study in chemical engineering, to Georgia Institute of Technology and Virginia Polytechnic Institute. Provisions for these grants are similar to those for the Eastman Kodak awards.

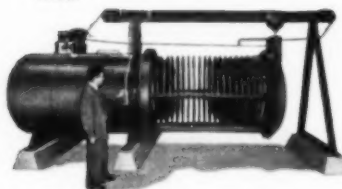
ALCOA INTRODUCES NEW DESICCANT

A new long-life desiccant with high sorptive properties for drying natural gas has been announced by Aluminum Co. of America. Called activated alumina H-151, the material is a specially prepared amorphous gel of activated alumina in ball form. Company engineers claim a design figure of 12 to 12.5% sorptive capacity for conditions similar to those tested, and negligible particle breakdown.

(More News on page 44)



FOR LIQUID CLARIFICATION Niagara Vertical Pressure-Leaf Filters are supplied in sizes handling up to 30,000 GPH. These filters are all-metal; leakproof; easily fabricated in stainless steel and other alloys; readily jacketed or lined to match your need.



FOR SOLIDS RECOVERY plus liquid clarification . . . Niagara Style "H" Pressure-Leaf Filters offer exceptionally fast removal of semi-dry cakes. Flow rates up to 45,000 GPH in one compact, leakproof unit.

if you wash your filter cake . . . this WASHING CURVE is good news for you

The curve shows what happens typically when you wash residual solvent or other liquid from the cake in a Niagara Pressure-Leaf Filter.

Notice how close this is to true displacement washing. Here's what it means in results:

You can wash 10% acid in mother liquor down to .01%, using only three volumes of wash liquor per volume of cake to get this high acid recovery.

Another example is vegetable oil. You can reduce 10% by weight of oil in the cake to .01% by solvent washing.

You can save as much as 1½ hours per cycle over conventional washing (or air blowing) methods.

You can cut recovery costs decisively. Roughly 50% less steam is needed for evaporation of wash liquor, since dilution is roughly 50% less than with other filters.

You can eliminate the cost and upkeep of a separate filter used only for washing.

If you'd like more facts about the Niagara washing curve, and what it can do for you, just write us or mail the coupon today.



Niagara Filter DIVISION
AMERICAN MACHINE AND METALS, INC.

Engineering and Sales Office: 3091 Main St., Buffalo 14, N. Y.

(When writing, please use above address)

Factory: East Moline, Illinois

IN EUROPE: Niagara Filters Europe, 36 Leidsegracht, Amsterdam-C, Holland

NIAGARA FILTER Division, American Machine and Metals, Inc.
3091 Main St., Buffalo 14, N. Y.

Please send information on Niagara Filters for _____ (product or operation)

Name _____

Title _____

Company _____

Address _____

City _____ Zone _____ State _____

MARGINAL NOTES

News of Books of Interest to Chemical Engineers

Living—A Science and An Art

Science and the Business of Living. James G. Vail. Pendle Hill Publications, Wallingford, Pa. (1953). 32 pp. 35 cents.

James G. Vail was the president of the American Institute of Chemical Engineers in 1946, and the pamphlet which we review here will be of interest to his many friends in chemical engineering who remember his talks on science and the spirit of man. This little book, edited and published by his friends in the Quaker movement, collects the best of the late James G. Vail's talks and papers as published in the scientific press. Four published articles are condensed here, two of them from "C.E.P."

Jim Vail, competent scientist in his own right (witness his volumes on the Silicates), was one voice of those thoughtful men who are troubled about the purpose and direction of science.

This book keeps that voice alive, and, as in the past, we hear Vail speak of the inadequacy to our life of the "dead facts stranded on the shore of the oblivious years," and again we stir as he jabs his finger of words on the hidden sore spots of our world. Ending this volume is the motto which we had reproduced and hung on the walls of our office for several years—"when confronted with the great problems of our time, resolve not to be part of the problem, but part of the answer."

All in all it is a sensitive pamphlet, well worth the time and the thinking it generates. Only one thing is missing; we wish it were an autographed copy.

F.J.V.A.

It's Still Two-Dimensional!

The Dynamical Character of Adsorption. J. H. de Boer. Oxford University Press, London (1953). 239 pp. \$6.00.

Reviewed by C. L. Mantell, Chairman, Chemical Engineering Department, Newark College of Engineering, Newark, N. J.

This might be described as a professional, philosophic volume attempting to create a picture of an adsorbed layer of gas, conforming to the two-dimensional concept of van der Waals. The chapters deal with n , the number of molecules striking each square centimeter of sur-

face per second; the time τ of lingering or residence, or the time of adsorption; the quantity σ , the product of n and τ ; uni- and multimolecular adsorption; the behavior of ideal two-dimensional gases; two-dimensional condensation, dipoles and surface forces; the specialized cases of isotherms of two-dimensional condensation; some effects of capillaries, all treated in a rigid mathematical manner but with a number of stringent simplifications necessary to allow the mathematical applications. All this is primarily under equilibrium conditions.

There have been a number of books on the theoretical aspects of adsorption, many of them confined as this volume is to certain phases of gas adsorption. As mathematical philosophy the book is interesting reading, perhaps mostly to the physicist or the physical chemist; to the chemical engineer practicing in the field, time may not be available or warranted.

Drawing Without Tears

Simplified Drafting Practice. William L. Healy and Arthur H. Rau, John Wiley & Sons, Inc., New York (1953). 156 pp. \$5.00.

As the authors tell in the preface, this book is not a manual of engineering drawing. Rather it is a summary of the revolution that took place when the General Electric Co. decided to simplify its drafting practices. Its purpose is to arouse in the engineering mind enthusiasms for the less complicated in drawings. As a philosophy the authors take as their guide the statement that the old-fashioned painstaking artistry of the professional draftsman is as outmoded as the horse and buggy, and that the practices of the men at the big boards can be stripped of their frills without surrendering either accuracy or clarity. The authors are concerned not only with a philosophy, however, but also get down to cases with simple and factual suggestions as to methods, equipment, and processes.

Chapter headings are indicative of the scope of the book and they cover: simplification, elimination of unnecessary work, freehand drawing, use of symbols, mechanical aids, abbreviations, arrowless drawing, simplified drafting, legible lettering, tolerances, instructions, drawing forms, and reproductions processes.

Revelations of Science

The Evolution of Chemistry. Eduard Farber. The Ronald Press Co., New York (1952). 349 pp. \$6.00.

Reviewed by A. H. White, Professor Emeritus, Chemical Engineering, University of Michigan, Ann Arbor, Mich.

The title of this book, not a history of chemistry, but "The Evolution of Chemistry," indicates a philosophical approach which adds something of a third dimension to a historical narrative. The attempts of the older civilizations to explain natural phenomena and the properties of matter as springing from the gods, were gradually clarified as study became more objective, but it was not until the complete abandonment of alchemistic beliefs that the direct influence of supernatural powers was eliminated from our thinking. The Greeks believed that the absolute truth could be found by pure reasoning. Farber states (p. 40) "The progress of chemistry during these thirteen centuries is small. . . . Science is revealed, not developed. . . . All that can possibly be achieved through experimentation is to confirm the teachings of reason." Of a somewhat later period he says "Galileo argued that odor, color, taste and sound are human sensations, not qualities inherent in matter." He thus proposed a new approach to the examination of scientific phenomena.

The book is divided into three major periods: I. The Emergence of Chemistry (93 pp.); II. The Development of Chemical Systems (146 pp.); III. Specialization and Industrialization (90 pp.). The third period which Farber dates from the decade of the 1880's is the era of intense industrial activity. Farber reviews some of the striking developments in basic science and their industrial applications. To this reviewer who has lived through much of this latter period, this is the least interesting part of the book. To those who are younger, and to whom the amazing developments of this latter period must be explained, it will be interesting reading.

Dr. Farber has been successful in his task, and has written an interesting account of the evolution of chemistry from the earliest records to modern times.

(More Marginal Notes on page 34)

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MARGINAL NOTES

(Continued from page 32)

Stimulating Non-Aqueous Thinking

Non-Aqueous Solvents: Applications as Media for Chemical Reactions. Ludwig F. Audrieth and Jacob Kleinberg. John Wiley & Sons, Inc., New York (1935). 284 + xii pp., \$6.75.

Reviewed by R. E. Treybal, Professor, Chem. Eng., New York University.

It is the stated purpose of this book "to show how non-aqueous solvents can be used as media for carrying out chemical reactions," and to stimulate thinking and research in this direction. To this end the authors have successfully applied the solvent-system concept to classify and to interpret the behavior of a number of liquids in their action as solvents.

In the two introductory chapters the physical properties of solvents which influence their usefulness, and the various reaction types such as metathesis, neutralization, and the like are discussed and a historical review is included, of several acid-base concepts. About one quarter of the book is devoted to liquid ammonia and related substances, and the solvent-system concept is used to develop the relationship of ammonia to other nitrogen-containing solvents. A separate chapter considers nitrogenous solvents such as amines, hydrazine, hydrogen cyanide and others. Acetic acid, sulfuric acid, hydrogen fluoride, etc., are each given a chapter.

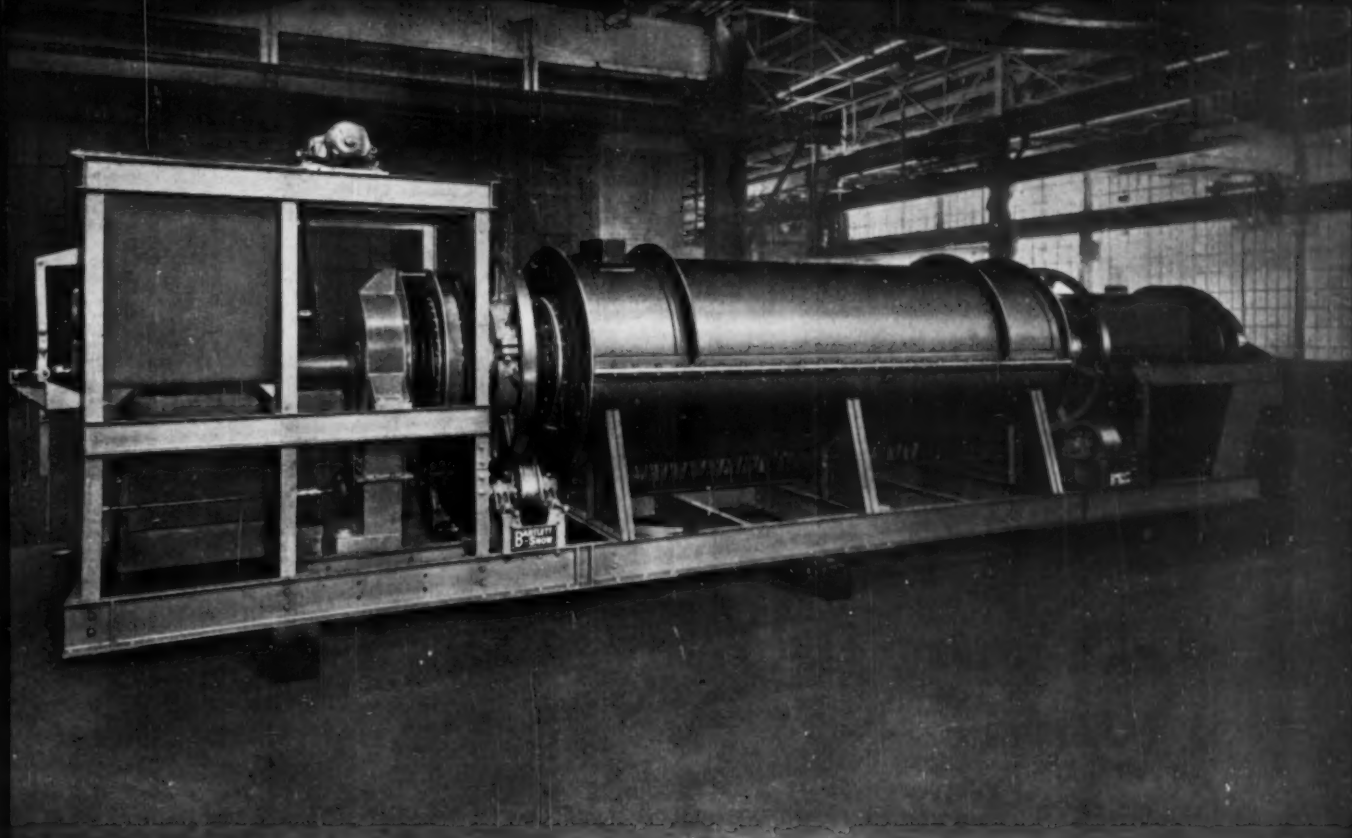
For each solvent the discussion includes a brief historical review, and a consideration of physical properties. The emphasis is on laboratory chemistry and no particular attention is paid to industrial applications or engineering techniques. However, the variety of possible chemical reactions and the different results which may be obtained in these relatively unfamiliar solvents over what may be done in water are put forth in readable style.

The more than 450 literature citations, which include references to patents, cover the period from 1768 to 1951, and a good index is provided. The book would seem to be of secondary interest to engineers, but indispensable to chemists unfamiliar with this field.

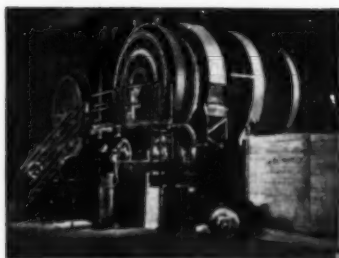
Books Received

Paint and Varnish Production Manual. Edited by Verne C. Bidlack and Edgar W. Fasig. John Wiley & Sons, Inc., New York (1951). ix + 288 pp. \$6.50

Applied Inorganic Analysis (second ed.) W. F. Hillebrand, and G. E. F. Lundell. Revised by G. E. F. Lundell, H. A. Bright, and J. I. Hoffman. John Wiley & Sons, Inc., New York (1953). xxii + 1034 pp. \$15.00.



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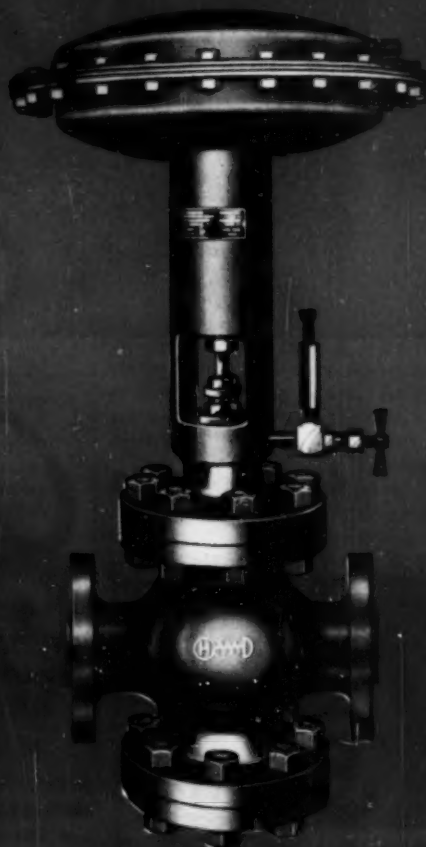
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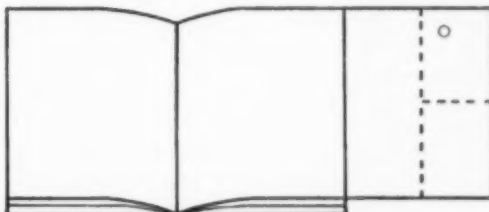
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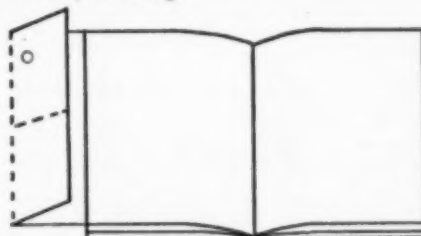
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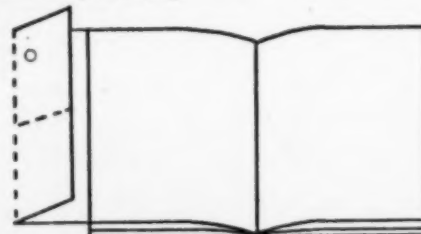
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- Spray Drying.** Brochure from Swenson Evaporator Co., division of Whiting Corp., covers advantages of spray drying, equipment, and processes. Flow sheets for drying variety of products; lists all types available.
- Forged Steel Fittings.** Forged steel pipe fittings from Watson-Stillman Co. listed in loose-leaf binder. Sections on uses, materials, types, specifications, dimensions, special alloys, and fittings.
- Corrosion-Resistant Linings.** Tygon corrosion-resistant linings described in bulletin from U. S. Stoneware.
- Tables of chemical resistance.** Linings available as calendered or press-polished sheeting, tubing, solid cord, or channel, etc.
- Centrifugal Pumps.** Nagle Pumps, Inc. bulletin on nine types of pumps designed for abusive industrial applications. Included are side suction, rear entrance, dry and wet pumps, some automatic. Cutaway views and specific applications.
- Durimet 20.** Bulletin on high strength, machinable, austenitic stainless steel, Durimet 20 by Duriron Co., Inc. Chemical composition, mechanical and physical properties. Degree of corrosion resistance to various chemicals tabulated and described.
- Spray Nozzles.** Technical details on Schutte and Koerting Co. atomizing and spray nozzles. Also construction details, characteristics, capacities, dimensions, etc. Applications in mixing, coating, cooling, washing and aerating liquids, to washing gases.
- Conveyor Handbook.** From Jeffrey Mfg. Co. a handbook on belt conveyors. Illustrates and describes typical applications, gives cutaway views, lists dimensions, weights, capacities, power specifications on each item in line.
- Tote System.** Complete system for solution of bulk-handling problems, Tote System, Inc. Mechanical, automatic system for filling, transporting, weighing, both bulk materials and liquids. For food, plastic, and other process industries. Table of case analyses on various materials, specifications, and illustrations.
- Ceramic Filters.** Ceramic vacuum filters from U. S. Stoneware Co. Bulletin covers diagrams, sectional illustrations, dimensions, also auxiliary equipment such as pumps, surge pots, etc. Construction materials are white chemical porcelain, glazed stoneware. Available with bodies in standard or heat-shock-resistant materials.
- Ejectors.** For efficient, low-cost air removal condensers, a line of steam jet air ejectors by Condenser Service and Engineering Co., Inc. Schematic diagram, operating principle, special service jets, accessories listed and described. Conversion and pressure tables.
- Rotary Pumps.** For the marine, petroleum, and process industries rotary pumps from Geo. D. Roper Corp. Leaflet on sizes and capacities, dimensions, construction, various types. Employ only two moving parts. Diagrams and illustrations.
- Mixers.** National Engineering Co. line of Simpson intensive mixers for the chemical process industries. Mulling action eliminates material balling; rapid discharge. Illustrated bulletin.
- Steam Condensers.** Dual bank surface condensers, various types and sizes, for stationary and marine services, described in C. H. Wheeler Mfg. Co. catalog. Conversion tables, vapor mixture data, tube characteristics, other pertinent information.
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- Cast Steel Valves.** From Edward Valves Inc. catalog on their angle, check, feed-line, and stop valves. Sizes 2½ in. and up. Material specifications, dimensions and weights, pressure-temperature ratings, other data.
- Hand Pumps.** Folder on vacuum hand pumps from Tokheim Oil Tank and Pump Co. for use in oil storage, refueling trucks, transfer of coolants.
- Installing Pumps.** Engineering study on proper installation of pumps from Viking Pump Co. Essentially for inclusion with catalog. Sections on improper installation, heads, viscosity, suction lifts, horsepower, pipe friction.
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BULLETINS

- 1 **Pumping Problems.** Geo. D. Roper Corp. bulletin on pumping problems. Punched for inclusion in a binder to serve as handbook for engineers with pump problems. Sample problems solved, technical data included.
- 2 **Spray Drying.** Brochure from Swenson Evaporator Co., division of Whiting Corp., covers advantages of spray drying, equipment, and processes. Flow sheets for drying variety of products; lists all types available.
- 3 **Forged Steel Fittings.** Forged steel pipe fittings from Watson-Stillman Co. listed in loose-leaf binder. Sections on uses, materials, types, specifications, dimensions, special alloys, and fittings.
- 4 **Corrosion-Resistant Linings.** Tygon corrosion-resistant linings described in bulletin from U. S. Stoneware.
- 5 **Tables of chemical resistance.** Linings available as calendered or press-polished sheeting, tubing, solid cord, or channel, etc.
- 6 **Centrifugal Pumps.** Nagle Pumps, Inc. bulletin on nine types of pumps designed for abusive industrial applications. Included are side suction, rear entrance, dry and wet pumps, some automatic. Cutaway views and specific applications.
- 7 **Durimet 20.** Bulletin on high strength, machinable, austenitic stainless steel, Durimet 20 by Duriron Co., Inc. Chemical composition, mechanical and physical properties. Degree of corrosion resistance to various chemicals tabulated and described.
- 8 **Spray Nozzles.** Technical details on Schutte and Koerting Co. atomizing and spray nozzles. Also construction details, characteristics, capacities, dimensions, etc. Applications in mixing, coating, cooling, washing and aerating liquids, to washing gases.
- 9 **Conveyor Handbook.** From Jeffrey Mfg. Co. a handbook on belt conveyors. Illustrates and describes typical applications, gives cutaway views, lists dimensions, weights, capacities, power specifications on each item in line.
- 10 **Tote System.** Complete system for solution of bulk-handling problems, Tote System, Inc. Mechanical, automatic system for filling, transporting, weighing, both bulk materials and liquids. For food, plastic, and other process industries. Table of case analyses on various materials, specifications, and illustrations.
- 11 **Ceramic Filters.** Ceramic vacuum filters from U. S. Stoneware Co. Bulletin covers diagrams, sectional illustrations, dimensions, also auxiliary equipment such as pumps, surge pots, etc. Construction materials are white chemical porcelain, glazed stoneware. Available with bodies in standard or heat-shock-resistant materials.
- 12 **Ejectors.** For efficient, low-cost air removal condensers, a line of steam jet air ejectors by Condenser Service and Engineering Co., Inc. Schematic diagram, operating principle, special service jets, accessories listed and described. Conversion and pressure tables.
- 13 **Rotary Pumps.** For the marine, petroleum, and process industries rotary pumps from Geo. D. Roper Corp.
- 14 **Leaflet on sizes and capacities, dimensions, construction, various types.** Employ only two moving parts. Diagrams and illustrations.
- 15 **Mixers.** National Engineering Co. line of Simpson intensive mixers for the chemical process industries. Mulling action eliminates material balling; rapid discharge. Illustrated bulletin.
- 16 **Steam Condensers.** Dual bank surface condensers, various types and sizes, for stationary and marine services, described in C. H. Wheeler Mfg. Co. catalog. Conversion tables, vapor mixture data, tube characteristics, other pertinent information.
- 17 **Chemical Pumps.** Rubber-lined Quimby centrifugal chemical and process pumps from Warren Steam Pump Co., Inc. Corrosion resistant, capacities to 2000 gal./min., heads to 125 ft., speeds to 3500 rev./min. small units, 1750 rev./min. large units. Diagrams, cutaway views, etc.
- 18 **Valves.** Chapman Valve Mfg. Co. valves and fittings. Binder catalog. For pressures 1500 lb./sq.in., temperatures -150° to 1000° F. Cross-sectional views, flow sheets, detailed charts for variety of materials.
- 21 **Cast Steel Valves.** From Edward Valves Inc. catalog on their angle, check, feed-line, and stop valves. Sizes 2½ in. and up. Material specifications, dimensions and weights, pressure-temperature ratings, other data.
- 22 **Hand Pumps.** Folder on vacuum hand pumps from Tokheim Oil Tank and Pump Co. for use in oil storage, refueling trucks, transfer of coolants.
- 23 **Installing Pumps.** Engineering study on proper installation of pumps from Viking Pump Co. Essentially for inclusion with catalog. Sections on improper installation, heads, viscosity, suction lifts, horsepower, pipe friction.
- 24 **Conveyor.** An efficient natural-frequency conveyor for use where pounds per hour carried is relatively small, described by Carrier Conveyor Corp. Available in 6- to 24-in. widths; lengths to 200 ft. with integral pans; ¼ to 3 hp. motors; speed of 30 to 35 ft./min. Does not slow down or dampen under load.
- 26 **Development Service.** To help develop machines, or processes from ideas to product. Proctor & Schwartz five-way service offers aid in research, development, engineering, manufacturing, and marketing. Folder available.
- 27 **Suction Pumps.** Open impeller centrifugal pumps, single suction by Taber Pump Co. Rating tables for 1750, 1150 rev./min. and smaller units, sectional-dimensional drawings, illustrations and descriptions.
- 28 **Rubber Parts.** Bulletin from Rubber Products Division of Parker Appliance Co. discusses new methods and processes from custom molding of seals, gaskets, discs. Resistance to temperature of -100° F. to +500° F.; corrosion; atmospheric conditions. Odorless and tasteless.
- 29 **Nickel.** Micro Metallic Corp. porous nickel sheet material, silicone treated, which will not pass water at less than 3 lb./sq.in., but passes air freely. For enclosing electric equipment, instruments, etc. May be cut to size, subjected to mild forming, can be welded to solid thread components or other fittings.
- 30 **Compressors.** Oil-free air compressors to eliminate lubricating oil from compressed air. Vertical, v-vertical, and semiradial types. Water-cooled, double-acting. Joy Mfg. Co.
- 31 **Sectional Coolers.** For cooling corrosive liquids and gases, Karbate impervious graphite sectional cascade coolers. Three models based on 9 ft. tube length and multiples. National Carbon Co. catalog section. Dimensional drawings, other data.
- 32 **Motors.** Reliance Electric and Engineering Co. a.c. and d.c. motors from ¾ to 300 hp.; heavy-duty types ¾ to 1000 hp.; electronic controls and regulators, etc.

- Microvac Pumps.** High vacuum pumps built by F. J. Stokes Machine Co. Flow diagrams, temperature charts, illustrations of models available, design views, descriptions.
- Waste Pumps.** For municipal and industrial installations, waste pumps from Marlow pumps. Bulletin describes plunger sludge, mud-hog diaphragm, self-priming centrifugal pumps.
- Autronic Manual Controls.** For remote operation of final control elements, Swartwout Co. bulletin on autronic manual controls. For use with other units of control, but can be used alone. Illustrations and schematic diagrams.
- Submerged Combustion.** Folder describes use of submerged combustion for heating corrosive liquids. Claims advantage of lower stack and radiation losses; fuel savings above 60%. Burners for hydrogen, propane, butane, where regular gas available. Submerged Combustion Co. of America, Inc.
- Precipitators.** For paper industry, Cottrell electrostatic precipitators for sodium salt recovery in soda and sulphate mills. Research Corp. folder shows diagram and cutaway view of wet-bottom design.
- Still and Accessories.** Precision Scientific Co. describes equipment for water distillation and storage. Size range 5 to 100 gal./hr.; storage tanks 10 to 500 gals. Specifications and diagrams. Steam, gas, and electric heat.
- Spray Nozzles.** For handling water and other liquids for cooling, humidifying, washing and other uses, spray nozzles from Yarnall-Waring Co. Four types. Diagrams, cutaway views, descriptions, all pertinent data.
- Conveyors.** Goodman Mfg. Co. announces shaker conveyors for moving abrasives, hot, wet, fine or bulky materials on level, up, or downgrade, distance to 500 ft. Capacity 100 ton/hr.
- Compressors and Pumps.** Twenty-one models of compressors and pumps of Pennsylvania Pump & Compressor Co.
- Automatic Scales.** Weightometer and Feedweight products of Merrick Scale Mfg. Co. One model weighs while conveying; the other feeds, weighs, and proportions by weight. For the lime, coal, chemical industries, mines, ore concentrate plants.
- Electric Valves.** Atkomatic Valve Co. folder on electrically operated solenoid valve. For pressures to 3000 lb./sq.in. Adjustable timing on closing stroke, available for pressures to 300 lb./sq.in., eliminates shock. Applications discussed. Operating diagrams shown.
- Separators.** Separator Division of Southwestern Engineering Co. bulletin on separators. For production screening and separation. Screens from 20 to 325 mesh. Large production capacity. Cutaway views, etc.
- Plastic Pipe.** Flexible, semirigid, high impact, and rigid plastic pipe from Triangle Conduit & Cable Co., Inc. Reference chart, tables of physical and chemical characteristics. For use in food processing, chemical plants, water systems. Resists corrosion, is light, odorless.
- Rubber Products.** Coverings and linings of rubber for tanks, pipes, fans, stacks, crystallizers, etc. from Raybestos-Manhattan, Inc. Lists products which do not oxidize or crack, are acid-proof. Used in food, plating, chemical, steel, pulp, glass industries.

Liquid Filters. Dollinger Corp. bulletin on Staynew liquid filters describes the radial fin construction, permits large filter area in small space. Wide range of filtered liquids are described. Capacities, pressure ranges, efficiency and low maintenance covered along with suggested filtering media for various uses. Data sheet included.

- Flange and Coupling Selector.** Nooter Corp. revised edition of flange and coupling selector. Lists outside diameter of flange, thickness, raised face, number of holes and diameter.

EQUIPMENT

- Portable Mixer.** Chemical and ceramic laboratory equipment from International Engineering, Inc. includes classifiers, portable mixers, jar and ball mills, pumps, etc. Sizes, capacities, other specifications.
- Pneumatic Positioner.** Republic Flow Meters Co. pneumatic positioning operator for high-speed positing. A pneumatic, electric flowmeter for fluctuating and dirty fluids also. Clearance dimensions, hook-ups, applications discussed.
- IMO Pumps.** DeLaval Steam Turbine Co. IMO rotary pumps. Specification table for capacities 10 to 500 gal./min., pressures 100 to 500 lb./sq.in. gauge. Services, materials, other features.
- Rotary Pressure Joints.** Johnson Corp. line of packless, self-adjusting, lubricating, and supporting rotary pressure joints. Sizes 1/4 to 3 in.. For paper machines, dryers, ash conveyors, rubber mills, etc.
- Magnetic Trap.** A sanitary full-flow magnetic trap by Tri-Clover Machine Co. 2-, 3-, and 4-in. sizes.
- Verticlosed Motors.** U. S. Electrical Motors, Inc. verticlosed pump motor. Sizes 1 1/2 to 400 hp. For deep-well turbine pumps. Downdraft ventilation, controlled lubrication, stacked bearings.
- Non-Corrosive Fastenings.** Nuts, bolts, screws in a variety of types and sizes available from H. M. Harper Co. Brass, bronze, copper, Monel, stainless, etc.
- Filters.** Stainless steel filter elements in two basic types from Micro Metallic Corp. Four possible arrangements, provide maximum filter surface in minimum volume. Bulletin contains engineering data, diagrams, tables.
- Dry Materials Flowmeter.** Massometer, a new flowmeter for measuring grain, dry chemicals, and cereal products. Announced by Wallace & Tiernan in leaflet and handbook insert in form of schematic drawing. Capacity 225 lb./min.; accuracy $\pm 1\%$ from 10 to 100% of capacity. Fitted for 5-in.-diam. spout, it is 24 1/2 in. high—26 in. wide.
- Mechanical Seal.** Dura-metallic Corp. catalog of Dura seals. For use with centrifugal and rotary pumps, autoclaves, agitators, etc. Corrosion resistant, seals gritty or abrasive fluids. Temperature range -40° F. to $+550^{\circ}$ F. Pressures 28 in. vacuum to 1000 lb./sq. in.
- Oil Reclaimer.** Hyflow continuous all-electric automatically operated oil reclaimers. Colored cutaway drawing illustrates system. For Diesel engines, compressors, turbines, transformers. Hilliard Corp.
- Industrial Waste Equipment.** Pumps, ejectors, clarifiers, distributors, and other equipment for use in treatment of water, sewage, and industrial wastes described in folder from Ralph B. Carter Co.

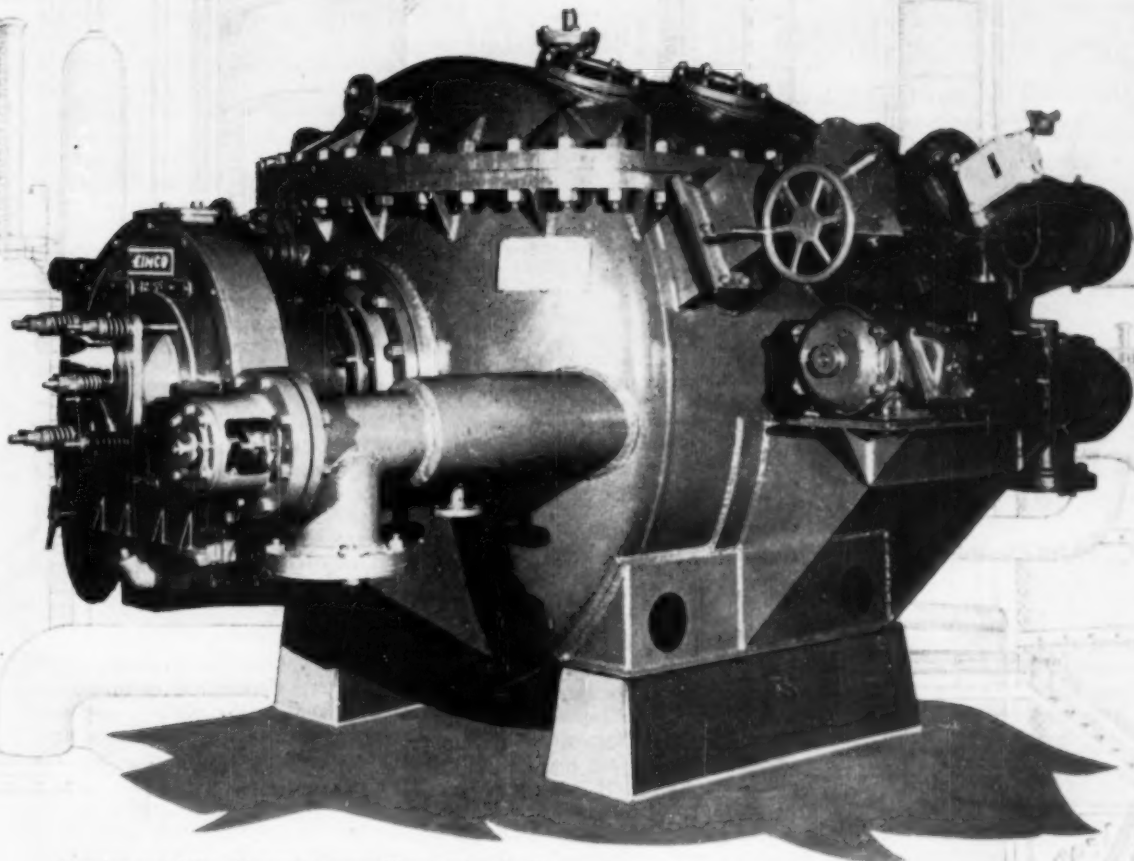
- Fans and Blowers.** Chelsea Fan & Blower Co. catalog of fans and blowers. Loose-leaf punched sheets for insertion in binder. Specifications, dimensions, ratings, etc.
- Water-Conditioning Equipment.** American Water Softener Co. desalers, softeners, feeders, etc., for boiler feed systems. Bulletin shows schematic drawings of each unit, gives details on function, and operation.
- Stainless Fittings.** New edition of Schnitzer Alloy Products Co. guide and reference book of stainless fittings. Sections individually tab-indexed for reference.
- Industrial Recorders.** Sanborn Co. booklet describing direct-writing industrial recorders.
- Feon Lab Coats.** Filtration Engineers, Inc. chemically resistant Feon lab coats of Vinyon-N fabric. Admiralty gray, is resistant to spots, acids, bacteria, mildew, etc.
- Stack Exhaust Heads.** V. D. Anderson Co. exhaust heads for industrial stacks to cleanse exhaust steam and vapors. No moving parts or filters. No nuisance particles vented. Guaranteed 99% effective. Efficiency increases with increase of velocity.
- Insulating Materials Index.** Chart for wall or binder use from Benjamin Foster Co. on insulating materials for thermal or refrigerated equipment, ducts, and pipelines.
- Automatic Controls.** Automatic Controlling, recording, telemetering instruments for every application, are subject of folder from Bristol Co. Controls are air- or electronically operated, and used in paper mills, oil refineries, smelters, food, chemical and process plants.
- Metal Hose Data.** From Universal Metal Hose Co. revised data book on complete line of metal hose. For both purchasing and engineering departments. Specifications, applications.
- Steam Generators.** Steam-Pak generators by York-Shipley, Inc. furnish high-pressure process steam or hot water. Automatic operation, oil and/or gas as fuel. Colored cutaway view. Features, specifications, ratings.
- Radiation Instruments.** Complete line of radiation detection and counting instruments from Nuclear Measurements Corp.
- Linings and Coatings.** Duro cements, linings, and coatings for acid tanks, floors, chemical process equipment, etc. from Electro Chemical Engineering & Mfg. Co. Tables on physical properties, quantities, etc.
- Flowmeter.** Flo-Watch meter for liquids, steam, air and gas by Builders-Providence, Inc. Transmitter attachment can actuate secondary instrument or act as remote control. Measuring range 25 to 100% of full scale. High accuracy. Descriptive leaflet.
- Loading and Unloading Equipment.** Thrower units for loading box cars over top of doors. Permits loading without entry of operator into car. Handles materials up to 2-in. size. Bulletin covers entire line of Stephens-Adamson Mfg. Co.
- Temperature and Humidity Cabinets.** Aire-Regulator with a temperature range from 10° below room (using tap water) to 140°F. Accuracy $\pm 1/2^\circ\text{F}$. Humidity range approximately 70 to 98% held at $\pm 1^\circ\text{F}$. Food Technology, Inc. Leaflet.
- Process Machinery.** From Traylor Engineering & Mfg. Co. leaflet on equipment for processing of ores. Covers crushers, dryers, feeders, various types of mills, etc. Details of construction, description, illustrations.

- Electronic Scale.** Brown Instruments Division, Minneapolis-Honeywell Regulator Co. describe Ametron electric scale using servo technique for industrial weighing. Designed for commercial and industrial weighing problems. For cranes, platforms, railroad tracks.
- Filter.** A filter said to hold output constant because filter medium never clogs, described in leaflet from Komline-Sanderson Engineering Corp. Filtration accomplished through helices of two sets of coiled springs laid in corduroy fashion.
- Finned Tubing.** Welded steel fin tubing from Drayer-Hanson, Inc. Sizes $3/8$ to 6 in. o. d.; lengths to 65 ft.
- Swing Joints.** Ball-bearing swing joints for loading and unloading oil, gasoline, chemicals, other liquids, by Barco Mfg. Co. From -30° to $+250^\circ\text{F}$; 1500 lb./sq.in. Sizes 2 to 4 in. Catalog.

CHEMICALS

- Fatty Acids.** From Armour Chemical Division: (100) Viscosity comparison chart on fatty acids, aliphatic amines, acetate salts. (101) A wall or file chart covering specifications, average composition and other details on neofat fatty acids. (102) A catalog covering amines, amides, nitriles, ethochemicals. Contains specifications, average composition and general information on uses.
- Vinyl Coating System.** Corrosion resistant, heavy-duty, drying-oil, primer, vinyl resin coating from Prufcoat Laboratories, Inc. To reduce poor adhesion, underfilm corrosion and rust creepage.
- Pittsburgh Chemicals.** (104) A new catalog of Pittsburgh Coke & Chemical Co. on insecticides, chemicals, plasticizers, etc. Formulas, uses and other data. (105) Brochure—The Story of Chemical X—or how one chemical developed from the inception of the idea through its commercial debut.
- Sodium Pentachlorophenate.** Santobrite, a sodium pentachlorophenate water-soluble preservative for water-base adhesives. Monsanto Chemical Co. Prevents microbial decomposition of animal or vegetable adhesive compounds. Specification tables included.
- Acrylic Acid.** Trial-lot quantities from American Cyanamid Co. Acrylic acid for preparing fibers, plastics, adhesives. Offered as a 50% solution in water. Bulletin contains formulas, reactions, other data.
- Cleaning Rubber Molds.** From Oakite Products, Inc. booklet on cleaning of rubber-processing equipment using special detergents which dissolve, emulsify and break up soils. Covers cleaning of molds, removal of lime scale, scale and rust prevention, etc.
- Thermoplastic Cement.** Availability of quick-setting thermoplastic cement for general industrial use announced by American Consolidated Dental Products Co. Applicable for gluing, bonding, filling. No air for setting.
- Udet F.** Synthesized specifically for use in the mixed fertilizer industry to give instantaneous solution in low moisture materials, are Udet F (50F and 90-95F). Effect ammoniation. Bulletin states techniques of use and advantages. Universal Detergents Inc.

CONTINUOUS PRESSURE FILTERS



Showing one of Eimco's newest pressure filters equipped for dewatering and washing with automatic precision scraper blade advancing mechanisms.

Every Eimco Filter for vacuum or pressure operation, or combination of the two, is a custom built machine designed and constructed to meet the specific requirements of your process.

The machine pictured above is another typical example of Eimco custom built filter design. This filter is part of the flow sheet in a plant producing phenol, acetone and alphas-methyl styrene. The purpose of the filter is to remove sodium sulphate crystals and small amounts of water and it was also necessary that the phenol in precoat cake be reduced to .05% washing with crude acetone and separating the strong and weak filtrates.

Eimco's testing and development departments are staffed with experienced chemical and metallurgical engineers whose work with consulting engineering firms

and the engineering departments of many producing companies has resulted in economies in operation and production of their product.

May we have an opportunity to consult with you and quote on your filter requirements?

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Memo from the Editor

One of our editorial questionnaires, which we send out every month to a small and varying group of readers, came back recently with the query, "Why don't you have a Letters-to-the-Editor section?"

The answer is that we do have such a section, but it is not published every month; chemical engineers are not consistent or persistent correspondents. But if the members feel that they would like such a column, or forum—fire away. We still must publish corrections to technical papers in the engineering section, but we can devote several columns a month to general letters, either in the front advertising section where we now run "Noted and Quoted," or in the back of the book among the News pages. But please—no "dogs are better than children" letters, keep them on a professional and an intelligent plane. Make them legible, sign them, and keep them succinct.

A.E.C. MAKES INDUSTRY NUCLEAR POWER REPORTS AVAILABLE

Reports of the four industry teams that investigated the feasibility of industrial nuclear power reactors are now available from the Government Printing Office. Publication late last month by the Atomic Energy Commission brings to the public declassified versions of the studies made by the Commonwealth Edison Co. and Public Service Co. of Northern Illinois; Dow Chemical Co. and Detroit Edison Co.; Monsanto Chemical Co. and Union Electric Co.; and Pacific Gas and Electric Co. and the Bechtel Corp.

The investigations were made by non-governmental engineers who spent a year working on the atomic energy program, appraising the economies of private participation in production of electric energy from nuclear reactors.

Industry was brought into the study under agreements with the A.E.C.: 1) to determine the engineering feasibility of the design, construction, and operation of reactors to produce power and fissionable material; 2) to examine the economic and technical problems of building such reactors; 3) to determine research and development needed; 4) to recommend industry's role in such a program.

The Commonwealth Edison Co.-Public Service Co. team investigated the economies of the gas-cooled, graphite-moderated reactor, and the heavy-water-moderated and cooled reactor. On the

basis of present reactor technology, the team felt that the heavy-water-reactor concept has the best economic possibilities. However, the report points out uncertainties as to the availability and cost of heavy water and the practicality and cost of a chemical plant to process fuel elements. Considerable advantage may be gained from the use of light water for moderating and cooling if uranium with a sufficient degree of enrichment can be obtained. Future cost of enriched fuel, and the dependability of the supply are uncertainties which would have to be resolved.

The report said that the gas-cooled reactor could provide a substantial beginning in atomic power with a minimum of interference to production reactors now under construction or contemplated. Both reactor designs described were feasible from engineering and operating standpoints, and assuming the availability of critical material, research facilities, and manpower, the research, final design, and construction ought to be carried out in about four years for the gas-cooled reactor, and about five years for the liquid-cooled reactor.

The Pacific Gas and Bechtel team made preliminary cost studies on the fast breeder reactor, the aqueous homogeneous reactor, and the heavy-water-cooled and moderated heterogeneous reactor. For detailed study two reactors were investigated, one a light-water-

cooled, heavy-water-moderated reactor, and a liquid-metal-cooled, fast reactor. The conclusion of this industry team was that, though the water-cooled thermal-type reactor has reached a point in engineering development which permits its construction, the liquid-fuel fast reactor appears to have the greater possibilities of low-cost-power production. However, in the latter case, the amount of development remaining to be done prevents the construction of such a reactor in the near future. They recommend that the development design of a liquid-metal-cooled, fast breeder with solid fuel elements be undertaken promptly; that on the completion of this design, construction be started unless the development of other types, such as the liquid-fuel reactor, makes the plans obsolete. Further, they recommend that the commission continue aggressive development of a liquid-fuel breeder reactor so that it can be programmed for commercial construction and operation.

Monsanto Chemical Co.-Union Electric Co. studied a number of different types of reactors and concluded that a sodium-cooled graphite-moderated reactor was the most promising to augment the plutonium supply. However, the report states that investigation of other systems shows some as possible, but later competitors of the sodium-cooled graphite reactor.

The Dow Chemical Co.-Detroit Edison Co. team concentrated on investigating a liquid-metal-cooled, fast-breeder reactor which would provide the high temperature necessary for efficient power recovery.

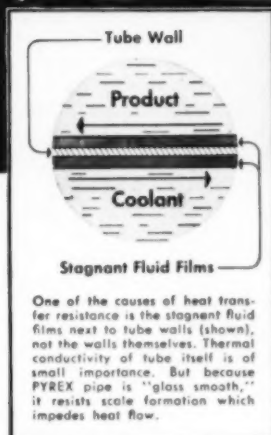
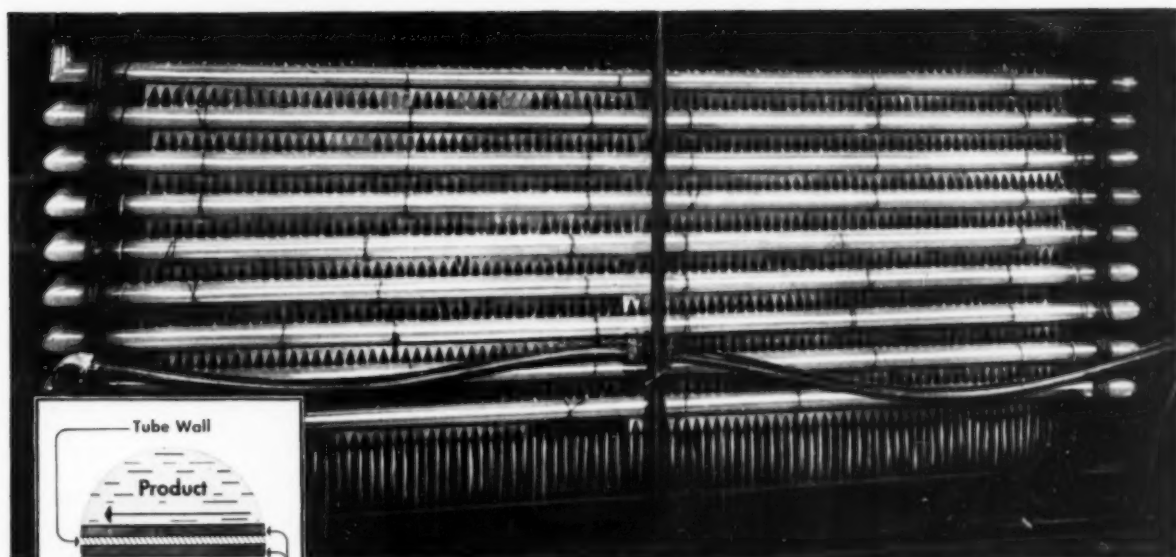
While the reports as issued by the government contain much information about reactor design, it is not a balanced picture of the originals, owing to security limitations. Each group settled on a different reactor type as holding most promise within the limit of the information already known in the A.E.C.

Cost of Power

On the basis of the Dow-Detroit Edison design, a nuclear reactor must be able to supply steam to the turbine throttle for a total cost of less than 59.4 cents 1,000,000 B.t.u. to be competitive with present modern boiler generation. The study helped to clarify, the report said, the point that nuclear steam generators will not affect the entire electric system investment. Actually, whether steam is generated in a nuclear reactor or in boilers, 80 to 85% of large utility investments would remain unchanged.

In the Monsanto Chemical Co.-Union Electric Co. report, three cases are compared for the cost of electric power—two nuclear and one a modern coal-fired plant. The cost in mills per kilowatt

(Continued on page 46)



PYREX CASCADE COOLER assembled of 18 standard 10-foot lengths of 2" PYREX heat exchanger pipe, arranged in two banks with standard PYREX U-bends at John Wiley Jones Company plant, Beech Grove, Ind. (Indianapolis). 15% solution of sodium hypochlorite bleach is circulated through the cooler at 35 GPM, under approximately 45 psi.

One Pyrex® cascade cooler saves 8 to 10 hours on every batch

Here's why it will pay you to check your present methods of manufacturing and processing chemicals and pharmaceuticals.

John Wiley Jones Company, manufacturer of "Sunny Sol" household bleach did just that. Now they save 8 to 10 man-hours on every 750-gal. batch of 15% sodium hypochlorite bleach. They did it by replacing previous equipment with one PYREX brand Cascade Cooler.

Because this installation at its Beech Grove, Ind. (Indianapolis) plant has proved so successful, the John Wiley Jones Company plans similar installations of PYREX Cascade Coolers in its other plants.

In this process, chlorine is absorbed into a 76% solution of sodium hydroxide as fast as possible, while the temperature of the solution is held below 85° F. Approximately 500,000 BTU (67,000 BTU per 100 gal.) must be dissipated through the PYREX Cascade Cooler while the 750-gal. batch is being chlorinated to a concentration of 15% sodium hypochlorite. Average time for this processing is about 3½ hours.

In addition to economical heat transfer efficiency PYREX Cascade Coolers offer exceptional resistance to virtually all acids (except hydrofluoric) and mild alkalis. This over-all corrosion resistance protects sensitive products and permits the use of low-cost river or sea water as a coolant.

Through transparent glass, you can watch the flow and easily detect air locks or other impediments. The hard, smooth surfaces clean easily; dust and scale yield quickly to a weak acid poured through the tubes. High physical and thermal strength of the glass itself minimize breakage.

PYREX Cascade Cooler units come completely packaged and can be installed in a day or less. To save space you can mount them on floor, wall or ceiling.

The coupon will bring you a wealth of helpful information on PYREX brand Cascade Coolers, Pipe, Fractionating Columns and other plant equipment. Mail it today.

Corning Glass Works

Dept. EP-6, Corning, New York

Please send me the printed information checked below:

- ☐ "PYREX brand Glass Pipe in the Process Industries" (EA-1)
- ☐ "PYREX brand 'Double-Tough' Glass Pipe and Fittings" (EA-3)
- ☐ "Plant Equipment Glassware for Process Industries" (EB-1)
- ☐ "Installation Manual" for PYREX brand "Double-Tough" Glass Pipe-(PE-3)
- ☐ "PYREX Cascade Coolers" (PE-8)

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Motion is important in making sizing tests. Conforms to recommendations for the motion to be used when making hand tests, issued by the Bureau of Standards.

Here, in the Newark "End-Shāk" unit, you get proper sustained hand motion mechanically. You get the best motion without being subjected to any human variation or weakness. This sturdy testing machine holds up to 7 full height sieves or up to 13 half height sieves. It is designed for 8 inch diameter sieves. Standard $\frac{1}{2}$ HP., 110-220 volt 60 cycle, 1750 rpm motor supplied. Special motor to order.

We'll be glad to send you prices and descriptive literature. And if you will outline your testing requirements we'll be glad to suggest the proper sieve series to use.

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A.E.C. REPORTS

(Continued from page 44)

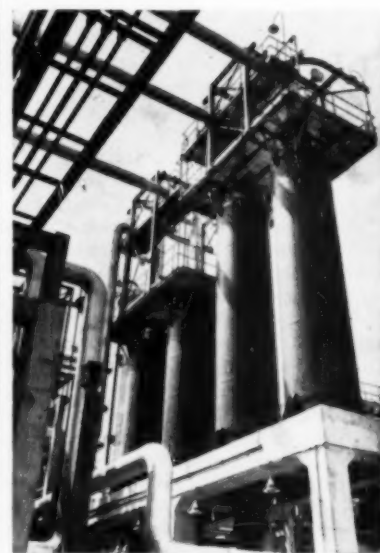
hour for one nuclear reactor was 4.13, for the second reactor it was 3.73, while the modern coal-fired plant was estimated at 3.97.

The Pacific Gas and Electric Co.-Bechtel Corp. report had costs of power ranging from 12.5 mills/kw.hr., down to 3.6 mills/kw.hr. depending upon plant and assumptions and purposes. It stated that atomic power from the immediately feasible nuclear power plants cannot compete with power from conventional steam electric plants now being constructed. This report stated that cost of power in a conventional plant is 6 mills/kw.hr.

Another case is given, however, in which a future atomic plant might produce power on a competitive basis with conventional methods. This is the liquid-metal-cooled fast reactor, which is adaptable to high-pressure, high-temperature steam conditions.

A gas-cooled reactor, Commonwealth Edison Co.-Public Service Co. estimate, would cost on the order of forty million dollars to build, for a gross electric power output of 61,700 kw. For the heavy-water-cooled reactor, construction costs are estimated to be \$118,000,000 for a gross electric power output of 225,000 kw.

Copies of the publication may be obtained from the Government Printing Office, Washington 25, D. C., for 25 cents.



A close-up view of four high-pressure reactors installed on the new Universal Oil Products Platformer at the Houston refinery of Shell Oil Co., Inc. The reactors are the largest yet constructed for any Platforming unit. Yearly production will be 19,000,000 gal. of benzene and 33,000,000 gal. of toluene.



WHICH ANODE will give you higher production? . . . You're absolutely right: you can't tell by looking. We can't either—and we've been making anodes for many years. Fact is, when it comes to anodes there's only one way to be sure: *test them on the job*. And with every new-type IGE Anode that's just what we do. First, of course, we build into it all the properties we know it should have—controlled density, uniform structure, high purity and mechanical strength, low electrical resistance. *But*—before we put it into production we first put it into actual operation in the process for which it was designed. We test it, we study it, we learn everything there is to know about its behavior. That way, we're never tempted to guess. We know that the high-production anodes are IGE Anodes. And so do our many customers.

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CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Active Members will receive careful consideration if received before July 15, 1953, at the Office of the Secretary, A.I.Ch.E., 120 East 41st, New York 17.

Applicants for Active Membership

Aries, Robert S., New York, N. Y.
Babiarz, Raymond S., Wilmington, Del.
Bliss, William M., Cleveland, Ohio
Bresler, Sidney A., New York, N. Y.
Bronson, Samuel C., New York, N. Y.
Cherney, Burton J., Wilmington, Del.
Crass, John W., Arlington, Mass.
Cundiff, Lester B., Wilmington, Del.
Drickamer, Harry G., Urbana, Ill.
Duffey, Donald K., Wilmington, Del.
Eister, W. K., Oak Ridge, Tenn.
Elliott, Quentin, China Lake, Calif.
Fish, Robert B., Piney River, Va.
Flanders, John E., Lakewood, Ohio
Ford, S. G., Wilmington, Del.
Frymoyer, T. D., Trenton, Mich.
Gardner, Samuel A., Hermosa Beach, Calif.
Gillman, H. H., Bloomfield, N. J.
Gilmore, David S., Richmond Heights, Mo.
Grampp, Harold J., Radford, Va.
Gray, John E., Aiken, S. C.
Hitchner, M. Johnson, Bridgeton, N. J.
Kelley, Arnold E., Long Beach, Calif.
Leedom, Richard P., Newark, Del.
Lehman, Jack E., Lomita, Calif.
Leventhal, Howard L., North Little Rock, Ark.
Lewis, Harold J., Houston, Tex.
Lindsay, Wesley N., San Jose, Calif.
Lord, William E., Ticonderoga, N. Y.
Marcelino, Joseph W., Richmond, Calif.
Moore, James R., Kirkwood, Mo.
Powers, Edward T., New York, N. Y.
Rapp, Harry W., Jr., Detroit, Mich.
Romanski, Alex J., St. Louis, Mich.
Ruebensaal, Clayton F., Waterbury, Conn.
Schellentrager, William S., Chagrin Falls, Ohio
Shatto, Paul F., Baltimore, Md.
Sindlinger, Charles J., Corpus Christi, Tex.
Smith, Leighton B., Beverly, Mass.
Sonia, Joseph A., Jr., Niagara Falls, N. Y.

Stewart, Robert M., Cambridge, Mass.
Strom, Barney O., Syracuse, N. Y.
Stromquist, W. K., Knoxville, Tenn.
Teague, James R., South Charleston, W. Va.
Tilton, Robert L., Petersburg, Va.
van der Pas, P. W., South Pasadena, Calif.
Waldvogel, Robert L., Akron, Ohio
Webster, Maurice L., Jr., Swarthmore, Pa.
Wiles, Charles R., Midland, Mich.
Yeames, Hawtrey J., Dighton, Mass.

Applicants for Associate Membership

Bartholomew, George G., Jr., Trenton, Mich.
Bradley, William R., Ponca City, Okla.
Brajihari, Vijan, Bengal, India
Curry, Lathey E., Jr., Lorain, Ohio
Forgey, Hurshel H., Independence, Mo.
Latham, Burton F., Jr., Dumas, Tex.
Maus, Louis, Jr., Bethlehem, Pa.
McMillin, F. William, New York, N. Y.
Moorhouse, W. A., Granville, Ohio
Reiss, R. H., St. Albans, W. Va.
Scerbo, Michael, Bristol, Pa.

Applicants for Junior Membership

Allen, Francis A., San Francisco, Calif.
Andrews, Eugene D., Pittsburgh, Pa.
Asti, Raymond A., Pittsburgh, Pa.
Atkins, Edward H., Manistee, Mich.
Bir, Wallace G., Louisville, Ky.
Blake, Carl, Jr., Henderson, Nev.
Bloomberg, Allan D., Springfield, Mass.
Bockman, David D., Evanston, Ill.
Brown, A. J. Terry, Jr., Los Angeles, Calif.
Brown, Richard C., Hammond, Ind.
Bundy, Patrick H., Jr., Glenshaw, Pa.
Busch-Petersen, Bent, Marton, Pa.
Comp, John R., Baltimore, Md.
Carpenter, Robert T., Frederick, Md.
Cavendish, John H., Tampa, Fla.
Cohen, Sydney, Texas City, Tex.
Colucci, Onorio, Akron, Ohio

(Turn to page 50)

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→
greater safety



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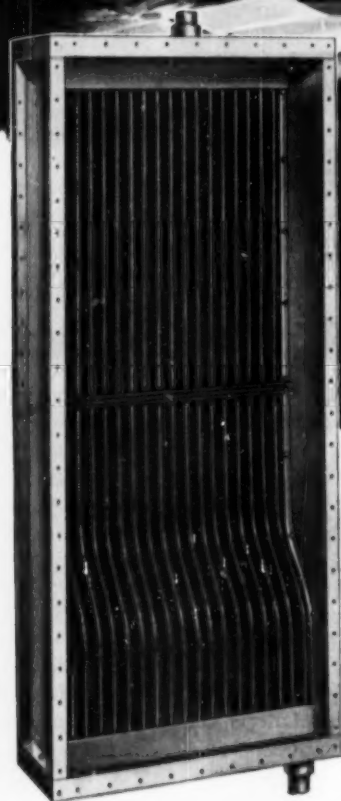
CP-6

Heating?

Cooling?

Air
Conditioning?

Process?

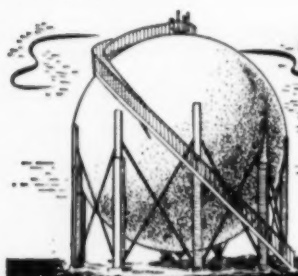


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CANDIDATES

(Continued from page 48)

Cramer, Robert L., Pittsford, N. Y.
Crim, H. C., Columbia, S. C.
Dingman, Robert W., Sharon, Mass.
Dodge, Donald W., Worcester, Mass.
Downey, E. P., St. Albans, W. Va.
Drobile, James A., Philadelphia, Pa.
Edwards, David O., Snyder, N. Y.
Falco, Nicola, Painesville, Ohio
Figel, Robert C., Chicago, Ill.
Fisher, Arthur L., Waltham, Mass.
Fleming, Ralph O., Decatur, Ala.
Freiberger, Arnold, New York, N. Y.
Gaffri, Robert L., Carteret, N. J.
Gavin, Arnold M., Bellaire, Tex.
Giegold, Wm. C., Pittsfield, Mass.
Goldin, Jay, New York, N. Y.
Gray, Donald N., Nitro, W. Va.
Gumprecht, Roland O., Richland, Wash.
Guyon, John, Pittsfield, Mass.
Hagenbach, William P., Buffalo, N. Y.
Hanratty, Thomas J., Urbana, Ill.
Hansotte, Roger J., Tarentum, Pa.
Huang, Chen-Jung, Toronto, Ontario, Canada
Humphrey, Albert S., Arlington, Va.
Hykan, Edwin H., Lemont, Ill.
Jessee, Gene L., Baltimore, Md.
Jester, Howard L., Baltimore, Md.
Johnson, David C., Liberty, N. Y.
Johnson, Samuel N., Pittsfield, Mass.
Kallman, Robert R., Wadsworth, Ohio
Kirk, J. Douglass, Springfield, Mass.
Knee, D. A., Penns Grove, N. J.
Koines, Charles W., Nyack, N. Y.
Lee, David C., Jr., Bishop, Tex.
Leiffers, William C., Long Beach, Calif.
Liermann, Theodore F., Schenectady, N. Y.
Lockhart, Roy E., Highland, Ind.
Mann, Alfred, Long Beach, Calif.
McFatter, William E., Lake Charles, La.
Mentzer, Cyril L., Philadelphia, Pa.
Molander, Lars E., South Charleston, W. Va.
Nixon, William A., Media, Pa.
Noon, W. L., Walnut Creek, Calif.
Ostrander, David L., Chicago, Ill.
Parker, James L., Jr., Beaver, Pa.
Perdue, Derril W., Nitro, W. Va.
Potts, John D., Minneapolis, Minn.
Reynolds, William M., Long Beach, Calif.
Rice, Robert H., Buffalo, N. Y.
Ruhlin, William B., Baton Rouge, La.
Schneider, Gilbert G., Hollywood, Calif.
Schuh, Russ, Niagara Falls, N. Y.
Seng, Wendelin C., Jr., Winnetka, Ill.
Shaw, John K., Bellerose, N. Y.
Shivalingiah, B., W. Lafayette, Ind.
Siegel, Bernard, Long Beach, Calif.
Simon, Lawrence M., Chicago, Ill.
Skovholt, Donald J., N. Augusta, S. C.
Soderberg, John Peter, Whiting, Ind.
Stone, Herbert L., Cincinnati, Ohio
Swingholm, Ralph S., Lyons, Ill.
Turner, E. W., Pittsfield, Mass.
Vass, Ernst, Galveston, Tex.
Walker, Albert, South Charleston, W. Va.
Wetzel, Roland H., Wilmington, Del.
Wise, William T., Bartlesville, Okla.
Zmudzinski, Edwin S., Scotia, N. Y.

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Ratographic* miniature indicators



- Graphic indication of process limits
- Flange-to-flange flush mounting
- Fully interchangeable in seconds
- Drum dial, linkless mechanism
- Fixed reading-point improves speed of scanning
- Scale-set adjustable high/low operating guides and alarms
- Plug-in unit easily removed with finger jack for check or change



Completely described and illustrated in Catalog 55-10. Write for it today.

Fits panel space only $2\frac{3}{8}'' \times 5\frac{3}{8}''$

yet with $5\frac{3}{4}''$ long, readable scale in keeping with $\frac{1}{2}\%$ accuracy.

Unique, new "graphic guides" mark high/low operating range, are adjustably mounted on scale drum and carry switch trippers to actuate alarms or take emergency action. Rotating drum dial and fixed reading point permit large, easily read figures and open, uniform scale. Building block construction of Ratographic indicators permits field addition of alarms and guides to the basic precision pneumatic indicator. Illustrated are two indicators which form a control selector station accessory for remotely mounted controllers.

*Trade Mark of Fischer & Porter Co.



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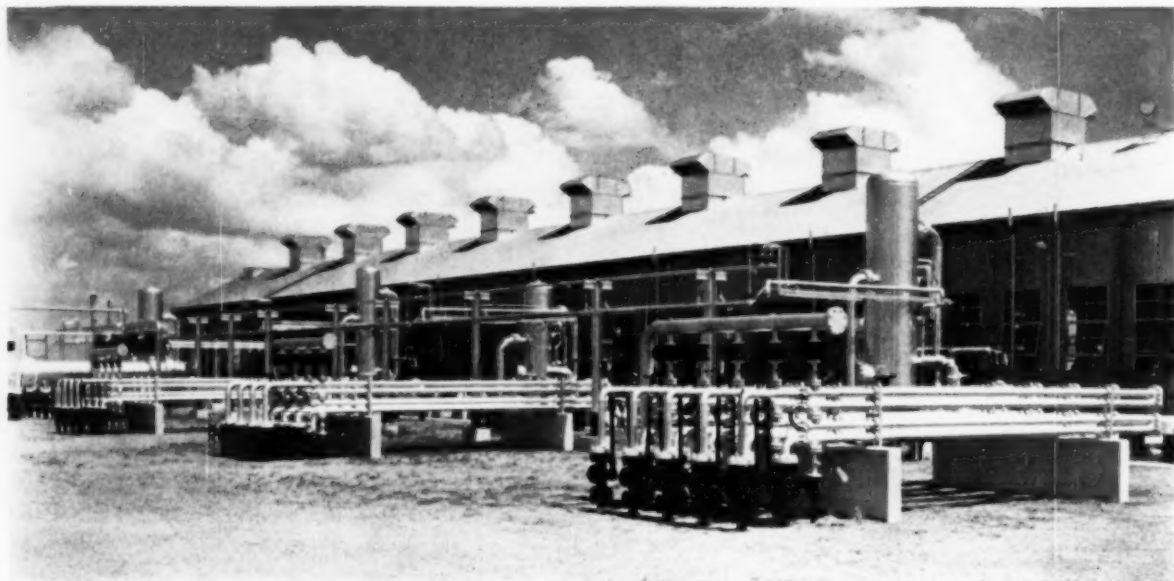
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2160

Assure Top Efficiency

in your plant with



BROWN FINTUBE *Sectional* HEAT EXCHANGERS

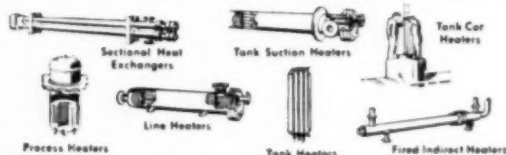
● Avoid the loss in efficiency that results from just a few thousandths of an inch of deposit on the tubes, by using Brown Fintube Sectional Exchangers for every heating and cooling service.

The longitudinal passages of Brown Fintube Sections control the material flow, eliminating baffles and the back eddies that encourage fouling. Their greater heating surface — 2 to 8 times that of bare tubes — permits more BTUs to be transferred at lower temperature per square foot of surface, minimizing "coking" and charring. Brown Fintube Sections are easy to clean — and — by simply manifolding a few extra sections into the unit, one stream after another can be taken off line for cleaning while the rest — always thoroughly clean — carry the unit's full rated capacity, year after year — without any shut-downs.

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MEMPHIS • BIRMINGHAM • NEW ORLEANS • SHREVEPORT • TULSA • HOUSTON • DALLAS • LOS ANGELES • SAN FRANCISCO • and ST. THOMAS, ONT.

Secretary's Report

S. L. TYLER

The Executive Committee met in the Offices of the Institute, New York City, May 8, and received the Treasurer's reports and approved Minutes of the previous meeting. All those whose names were listed in "C.E.P." for April, 1953, were elected to the grades of membership indicated with the exception of two applicants whose cases will require further consideration.

Sixty-three Student members were elected. Three members were placed on the Suspense List because they entered the Armed Forces and two members were removed from it since they had returned to civilian life.

R. S. Fey was appointed counselor of the student chapter at the University of Maryland to succeed J. H. Bilbrey, Jr. Arthur Rose was appointed counselor of the student chapter at Pennsylvania State College succeeding D. S. Cryder.

R. D. Sheeline was appointed representative of the Institute at the dedication of the New School of Engineering and Architecture Building at Howard University, Washington, D. C.

The Council of the Institute met at The Chemists' Club on May 8; only one member was absent. The Minutes of previous meetings were approved.

The resignation of C. R. DeLong as Treasurer of the Institute was accepted, effective June 1, 1953, and G. G. Brown was appointed as his successor.

L. P. Scoville, chairman of the Program Committee, appeared before Council and discussed important matters.

The Auditor's report for 1952 was presented, discussed and accepted, and ordered published.

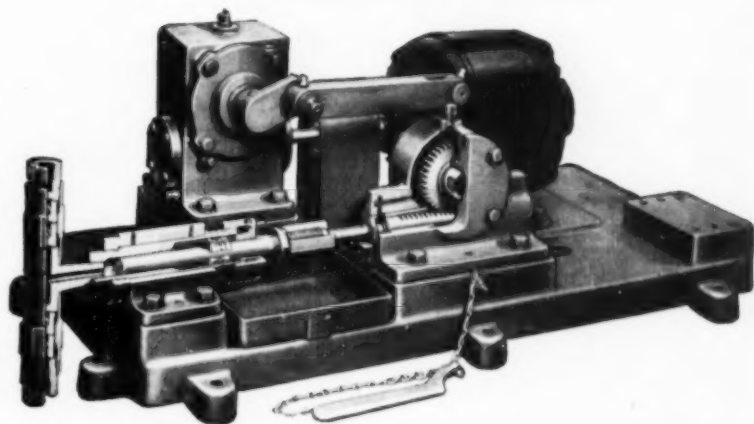
Upon recommendation of the Institute Sections Committee, approval was given to the application for local section status from the Tidewater Virginia Chemical Engineers Club to become the Tidewater Virginia Section of the Institute.

Recommendations were received and approved from the Chemical Engineering Education and Accrediting Committee on the accreditation of the chemical engineering curriculum at 17 schools.

J. C. Elgin was appointed Institute representative on the Division of Chemistry and Chemical Technology of the National Research Council for a three-year term beginning July 1, 1953. N. A. Shepard was appointed Institute representative on the Division of Engineering and Industrial Research of the National Research Council for a three-year term beginning July 1, 1953.

The next meeting of the Council was scheduled for June 15 in New York City with the agenda carrying special policy matters to be discussed in detail.

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metering and proportioning
of small volume flows...**



... the HILLS-McCANNA "U" Type Proportioning Pump

• The Hills-McCanna "U" Type Pump is designed to continuously meter and proportion small flows of the order of 0.10 to 24 gallons per hour per feed. Its accuracy and reliability suit it for research, pilot plant operation and full scale processing alike. The "U" type pump is suitable for batch or continuous operations.

Typical examples of "U" type pump applications include:

- Continuous addition of air entraining agents during cement manufacturing operations.
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The new "U" Pump Catalog, UP-52, gives full information on the "U" type pump plus extensive application data including specific service recommendations for handling over 300 substances. Write for your copy, today. HILLS-McCANNA CO., 2438 W. Nelson St., Chicago 18, Ill.

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**Also Manufacturers of: Saunders Patent Diaphragm Valves
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Here is a
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RESPECTED
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CHEMICAL PROCESS INDUSTRIES

It means specialized experience in the fabrication of completely integrated heat exchanger units that are

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Rugged in construction . . .
Designed for easy service . . .

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Solvent Recovery Equipment
Extraction Coils
Evaporators
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Condensers (for any Vapor)
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Exhaust Waste Heat Boilers
Quenching Oil Coolers
Storage Tank Heaters
Fractionating Equipment
Self-Cleaning Heat Exchangers
& Gas Coolers

A stainless steel Reflux Condenser,
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NEW YORK 20, NEW YORK

TREASURER'S REPORT

The accompanying balance sheet and statement of income and surplus have been examined by F. W. Lafrentz and Co., certified public accountants of 100 Broadway, New York, N. Y., and in their opinion present fairly the financial position of the American Institute of Chemical Engineers at December 31, 1952, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

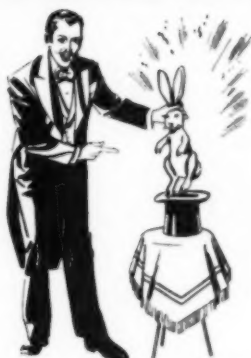
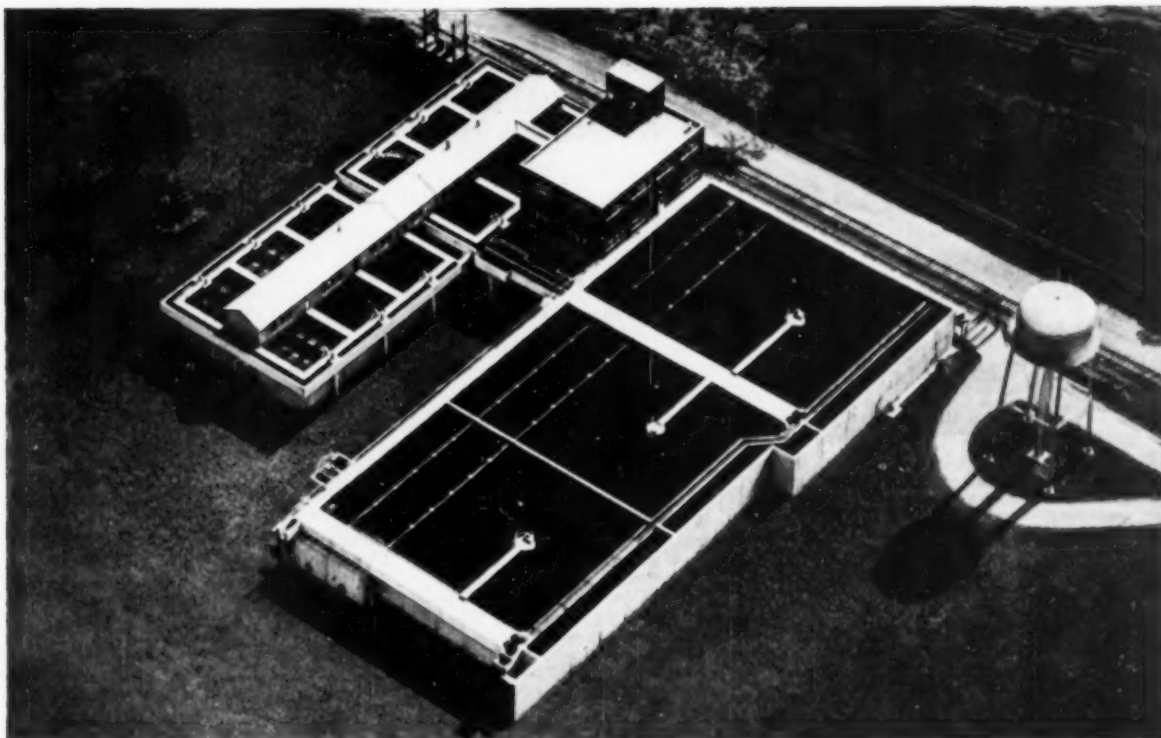
G. R. DeLONG, Treasurer

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

COMPARATIVE BALANCE SHEET, DECEMBER 31, 1952 AND 1951

	Assets		1952	1951			
Current Assets:							
Cash on hand and demand deposits			\$181,104.83	\$110,110.83			
U. S. Government and other securities, at cost including accrued interest and dividend (total market value and re- demption value, 1952, \$96,390.50; 1951, \$95,757.00)			97,613.63	96,480.55			
Accounts Receivable:							
Membership dues and entrance fees, less reserve for doubtful accounts	\$ 1,170.32		\$ 1,478.50				
Advertising, subscriptions, etc.	14,780.59		12,115.64				
Meetings advances	1,200.00		2,300.00	15,894.14			
Inventory, at cost:							
Paper stock	\$ 5,851.85		\$10,390.10				
Postage stamps	1,066.22	6,918.07	463.85	10,853.95			
Total Current Assets			\$302,787.44	\$233,339.47			
Deposits at U. S. Post Office and United Air Lines, Inc.					1,118.02		1,040.31
Furniture and fixtures, at cost less depreciation			14,821.83	10,878.14			
Deferred charges			374.90	176.05			
Total			\$319,102.19	\$245,433.97			
Trust and Special Funds:							
Cash on deposit	\$38,743.42						
Investments at cost, (quoted market value \$2,917.50)	2,955.00	41,698.42					
Total			\$360,800.61	\$245,433.97			
Liabilities							
1952					1951		
Current Liabilities:							
Accounts payable, printing and other expenses			\$ 6,678.15	\$ 11,431.24			
Total Current Liabilities			\$ 6,678.15	\$ 11,431.24			
Deferred Income:							
Dues	\$92,475.62		\$54,023.65				
Subscriptions	12,034.83		10,337.69				
Other	1,266.00	105,776.45	1,887.22	66,248.56			
Reserves:							
Chemical Engineering Education Projects Fund	\$ 2,602.83		\$ 2,394.44				
Student Meetings Fund	41.26		41.26				
Frederic E. Bowman Fund	1,000.00						
Magazine publication program	46,742.45	50,386.54	26,614.90	29,050.60			
Surplus		156,261.05		138,703.57			
Total			\$319,102.19	\$245,433.97			
Trust and Special Funds, Principal:							
Albert E. Marshall Fund	\$ 3,000.00						
Research Committee Project	38,698.42	41,698.42					
Total			\$360,800.61	\$245,433.97			

(Continued on page 56)



There's No "Magic Formula"

Every water treatment problem is different

No two water treatment problems are exactly alike. To get the best — and most economical — answer to your specific problem requires careful analysis of raw water composition, rate of flow and the results you require.

There is no magic formula . . . no single equipment unit that will give ideal results under all conditions. That's why it will pay you to check both conventional and high-rate units on every water treatment problem.

For a brief picture of the complete Dorr equipment line ask for Bulletin #9141. The Dorr Company, Stamford, Conn.

Repeat order in 1950 "proves out" a "conventional" installation made in 1948.

Quick facts about the Dorrco installation at the Hollingsworth & Whitney Co., Chickasaw Mills, Mobile, Alabama 1948 . . . First order installed with a design capacity of 10 MGD.

- 2 Dorrco Flash Mixers
- 1 Dorrco Flocculator
- 1 Dorrco Squarex Clarifier, 85' square

Operating Results . . .

- Raw water: Color — 65-70 ppm
- Raw water: Turbidity — 3.5-3.9 ppm
- Finished water: Color — 3 ppm
- (Dosage in ppm: Alum 20, Soda Ash 15, Chlorine 3 to 5)

1950 . . . Second order installed with design capacity of 16 MGD. (Total design capacity: 26 MGD)

- 1 Dorrco Flash Mixer
- 2 Dorrco Flocculators
- 2 Dorrco Squarex Clarifiers, 75' square

Flocculator and Squarex are trademarks of THE DORR COMPANY—Reg. U. S. Pat. Off.

Every day, nearly 8 billion gallons of water are treated by DORR equipment.



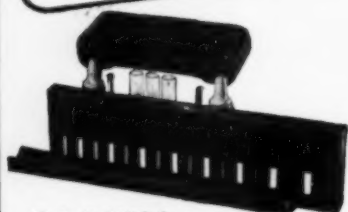
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Offices, Associated Companies or Representatives in principal cities of the world.

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Taylor Model T-O Comparator for pH. Slides available for pH as low as 0.2 or as high as 13.6. Phosphate slides work on same base. Chlorine comparators also available.

TAYLOR COMPARATORS with GUARANTEED COLOR STANDARDS

EASY TO USE--

Taylor Comparators use the familiar colorimetric method of comparison . . . but without the need for handling fragile single standards. Each complete set of Taylor Liquid Color Standards in sturdy plastic slide, many slides usable on one base.

FAST TO USE--

many determinations can be made in a matter of seconds, others take no longer than two minutes.

CONVENIENT TO USE--

you can carry the lightweight set to the testing spot, no necessity for carrying solution samples back to the lab.

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because all Taylor Liquid Color Standards are unconditionally guaranteed against fading, thus there is no chance of mechanical inaccuracy.

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See your lab supply dealer for Taylor sets or write direct for free copy of this informative handbook, "Modern pH and Chlorine Control". Describes theory of pH and chlorine control, illustrates full Taylor line.



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TREASURER'S REPORT

(Continued from page 54)

COMPARATIVE STATEMENT OF INCOME AND SURPLUS FOR THE YEARS ENDED DECEMBER 31, 1952 AND 1951

INCOME:	1952	1951
Membership dues	\$175,122.11	\$166,452.47
Less allocation to subscriptions (at \$4.50 per member)	55,306.85	53,724.54
Membership entrance fees	14,934.00	14,030.00
Magazine income	258,874.23	206,388.18
Emblems and binders, net sales	900.41	899.85
Surplus from meetings	1,363.03	2,270.96
Income on investments	2,352.83	1,500.65
Total income	\$398,239.76	\$337,817.57
EXPENSES:		
General Operations:		
Magazine expenses	\$125,700.65	\$109,064.07
Salaries and commissions	154,833.75	121,784.65
Employees Retirement Plan	4,356.31	4,898.32
Federal Insurance Contributions	1,496.06	1,197.06
Rent and electricity	13,066.66	12,801.00
Printed material, stationery, postage, telephone and telegraph	30,118.13	18,540.07
Meetings expenses, travel, etc.	11,737.03	11,110.03
Auditing and insurance	1,959.72	1,364.85
Awards	1,677.19	1,806.59
Provision for depreciation—furniture and fixtures	2,646.25	1,994.99
Provision for doubtful accounts—dues	3,262.00	3,021.60
Miscellaneous	4,360.63	3,711.16
	\$355,214.38	\$291,294.39
Other Expenses:		
Participation and contributions to professional groups	\$799.48	\$3,464.40
Committee expenses	3,125.89	1,787.19
Sundry publications, cost less sales	1,414.98	1,790.17
	5,340.35	7,041.76
Total expenses	\$360,554.73	\$298,336.15
Net income for year	\$ 37,685.03	\$ 39,481.42
Surplus at beginning of year	165,318.47	125,837.05
	\$203,003.50	\$165,318.47
Deduct:		
Reserve for magazine publication program	\$55,000.00	\$ 55,000.00
Less net expenditures to end of year	8,257.55	28,385.10
	\$ 46,742.45	\$ 26,614.90
Surplus at end of year	\$156,261.05	\$138,703.57

INDUSTRIAL GRANTS WERE INCREASED IN 1952-53

Over a thousand college scholarships and fellowships were made available during the past year by chemical and related companies, according to a survey just completed by the Manufacturing Chemists' Association, Inc. The grants ranged in value from \$300 to \$5,000 a year. This represents a substantial increase over previous years, the Association said.

The M.C.A. survey showed a total of 34 companies providing 1,036 scholarships and fellowships having an annual value of \$1,618,000. This does not include funds given to educational institutions in the form of grants-in-aid or in support of research.

Of the total grants to students, 611 were scholarships available to undergraduates, while 425 were fellowships open to students doing graduate or post-graduate work, chiefly in engineering or the natural sciences. Generally, the grants were turned over to selected colleges and universities, which in turn chose the recipients and administered the scholarships, the Association said. It further stated that a recent and growing practice is for the contributing company to provide, in addition to student assistance, a grant-in-aid to the college during the life of the scholarship to help defray general operating expenses.

LOCAL SECTION

The Central Virginia Section held a dinner meeting at the Hotel Albemarle, Charlottesville, Va., April 24, 1953, at which seventy-one members and guests were present. George C. Gross, head of the Sectional Education Committee, told about the work of this committee during the past year. In an effort to educate the high school students on the various functions of chemical engineering, he said that 790 high school students were contacted and 1200 pieces of literature disseminated. One of the main points brought out was that at least 60 per cent of the students contacted were deficient in mathematics. J. H. Mallinson, reported the meeting.

At the annual and last meeting of the season on April 24, Ichthyologists (Boston Section) were presented with a double-barrelled program on crime detection by Captain Frank Wilson of the Homicide Squad of the Boston Police Department and Frank Stratton, biological chemist, Bureau of Criminal Investigation of the Boston Police Department. The program, says A. G. Smith, secretary, included descriptions, discussions, and slide illustrations of actual cases in the Boston Police Department records.

Elections were also held at the annual meeting and the following members were voted into office for the 1953-54 season:

Kingfish (Chairman)—Randolph Antonsen, Godfrey L. Cabot, Inc.
Mackerel (Vice-Chairman)—William C. Rousseau, Badger Manufacturing Co.
Smelt (Secretary)—Arthur G. Smith, Monsanto Chemical Co.
Shark (Treasurer)—Craig W. Angell, Artisan Metal Products Co.

Old Dixie Barbecue was the scene on May 19 of a meeting of the Southern California Section when Frank Kuenzly, plant manager, Shell Chemical Corp., Ventura, Calif., talked on synthesis of ammonia in the United States. S. G. Sevougian, reporting the meeting, says that Mr. Kuenzly covered the history of and recent developments in the ammonia field.

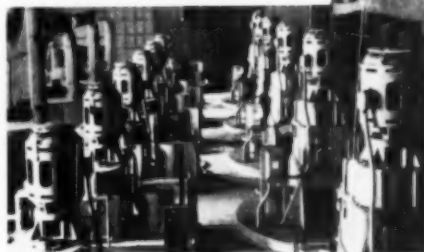
A recent meeting of the Cleveland Section consisted of a student presentation. J. Ennis, Case Institute of Technology, gave a talk "DMC Miticide Production." The Fenn College talk was by T. Rivenbark. His subject was "The Effect of Resin Additives on the Strength of Portland Cement." An advisory panel from the membership questioned the students and made comments on their papers. The panel consisted of the following men: A. E. Chute, A. G. McKee Co., C. E. Ford, National Carbon Co., D. W. Robb, J. F. Goodrich Chemical Co., and G. G. Thompson, Standard Oil Co. of Ohio.

Wilfred H. Charbonnet sent a report on this meeting.

(More Local Section on next page)

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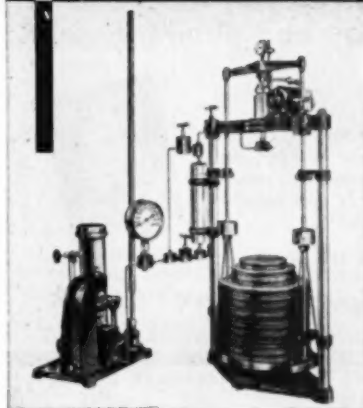
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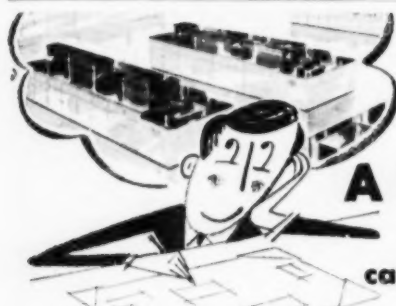
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Members of the Chicago Section were a pep group on the evening of April 22 for a dinner meeting at the Builders Club when "Keeping Posted with the A.I.Ch.E.," a panel discussion featuring Institute affairs, attracted a large crowd. W. T. Nichols, President of the Institute, Stephen Tyler, Secretary, and F. J. Van Antwerpen, editor of Chemical Engineering Progress, were present and heard such subjects discussed as the following:

Institute Management—what are its shortcomings?

Junior Membership—its representation.

Council Meetings—what happens at them?

See next issue for report on the election of new officers.

T. J. Carron, secretary of the Detroit Section, reported that on May 5, in rooms C and D of the Engineering Society of Detroit, Collin M. Doyle, vice-president and sales manager of Podbielniak, Inc., spoke on centrifugal solvent extractors.

The speaker at the April meeting of the Northern California Section was G. L. Longsdorf, Standard Oil Company of California. His subject was "Oil from the Near East." In discussing the importance and extent of Near East petroleum, he was able to draw on a considerable background to present a talk that was both entertaining and informative, according to D. F. Rynning, reporter.

At a previous meeting, E. D. Howe, associate dean, College of Engineering, University of California, discussed sea water refining.

A progress report on the activities of the Terre Haute Section was sent in by S. G. Bankoff, secretary.

On April 28 the following officers were elected for the next year: B. J. Quinn, Chas. Pfizer & Co., chairman; S. G. Bankoff, Rose Polytechnic Institute, vice-chairman; B. L. Lubin, Commercial Solvents Corp., secretary, and D. Thompson, Commercial Solvents Corp., treasurer. T. W. Cundiff, Chas. Pfizer & Co., C. W. Stahl, Du Pont, and J. W. Russell, Ohio Oil Co., make up the executive committee.

James Reichelt, chief engineer, Chas. Pfizer & Co., formerly chief, chemical construction division, National Production Authority, spoke on "How to Make Your Way Around Washington." Mr. Reichelt outlined the functions and organization of the N.P.A. and gave some examples of how it operates.

This Section has established an award at Rose Polytechnic, paying for the expenses of the student who participates in the annual Regional Student Chapter Conference. This year the award went to R. Alan Klaus, who spoke at the University of Detroit on April 11 on "Coal Hydrogenation."

For news of the Philadelphia-Wilmington Section, see the story of the Zeisberg Awards on page 20.

(More Local Section on page 60)

FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

Chairman of the A.I.Ch.E. Program Committee
Loren P. Scoville, Jefferson Chemical Co.

260 Madison Ave., New York 16, N. Y.

MEETINGS

San Francisco, Calif., Fairmont Hotel, Sept. 13-16, 1953.

TECHNICAL PROGRAM CHAIRMAN: R. W. Moulton, Head, Dept. of Chem. Eng., University of Washington, Seattle, Wash.

Annual—St. Louis, Mo., Hotel Jefferson, Dec. 13-16, 1953.

TECHNICAL PROGRAM CHAIRMAN: R. M. Lawrence, Monsanto Chem. Co., St. Louis 4, Mo.

Washington, D. C., Statler Hotel, March 8-10, 1954.

TECHNICAL PROGRAM CHAIRMAN: George Armistead, Jr., Consult. Chem. Eng., George Armistead & Co., 1200 18th St. N.W., Washington 6, D. C.

Springfield, Mass., Hotel Kimball, May 16-19, 1954.

TECHNICAL PROGRAM CHAIRMAN: E. B. Fitch, Asst. to Res. Dir., The Dorr Co., Westport, Conn.

Ann Arbor, Mich., Univ. of Mich., Ann Arbor, Mich., June 20-25, 1954—Conference on Nuclear Engineering.

TECHNICAL PROGRAM CHAIRMAN: D. L. Katz, Chairman, Dept. of Chem. and Met. Eng., Univ. of Mich., 2028 E. Eng. Bldg., Ann Arbor, Mich.

Glenwood Springs, Colo., Hotel Colorado, Sept. 12-16, 1954.

TECHNICAL PROGRAM CHAIRMAN: Prof. C. H. Prien, Dept. of Chem. Eng., Univ. of Denver, Denver 10, Colo.

Annual—New York, N. Y., Statler Hotel, Dec. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

SYMPOSIA

Ion Exchange

CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

MEETING—San Francisco, Calif.

Mixing

CHAIRMAN: J. H. Rushton, Dept. of Chem. Eng., Illinois Inst. of Tech., Chicago, Ill.

MEETING—San Francisco, Calif.

Transport Properties

CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Company, Baytown, Texas.

MEETING—San Francisco, Calif.

Applied Thermodynamics

CHAIRMAN: W. C. Edmister, Calif. Res. Corp., 576 Standard Ave., Richmond, Calif.

MEETING—San Francisco, Calif.

Fluid Mechanics

CHAIRMAN: R. W. Moulton, Head, Dept. Chem. Eng., Univ. of Washington, Seattle, Wash.

MEETING—San Francisco, Calif.

Distillation

CHAIRMAN: D. E. Holcomb, Dean of Eng., Texas Technological College, Lubbock, Tex.

MEETING—St. Louis, Mo.

Dust and Mist Collection

CHAIRMAN: C. E. Lapple, Dept. of Chem. Eng., Ohio State University, Columbus 10, Ohio.

MEETING—St. Louis, Mo.

Drying

CHAIRMAN: L. E. Stout, Dept. of Chem. Eng., Washington Univ., St. Louis 5, Mo.

MEETING—St. Louis, Mo.

Use of Computers in Chemical Engineering

CHAIRMAN: John R. Bowman, Head, Dept. of Res. in Phys. Chem., Mellon Institute of

Industrial Research, Pittsburgh 13, Pa.

MEETING—St. Louis, Mo.

Heat Transfer

CHAIRMAN: D. L. Katz, Chairman (Address: See Ann Arbor Meeting).

MEETING—St. Louis, Mo.

Carbonization

CHAIRMAN: R. S. Rhodes, Asst. Mgr., Prod. Dept., Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.

MEETING—St. Louis, Mo.

Industrial Waste Disposal

CHAIRMAN: K. S. Watson, Coordinator, Waste Treatment, Mfg. Facilities Serv. Dept., Gen'l. Electric Co., 202 State St., Schenectady, N. Y.

MEETING—St. Louis, Mo.

Nuclear Engineering

CHAIRMAN: D. L. Katz, Chairman (Address: See Ann Arbor Meeting).

MEETING—Ann Arbor, Mich.

Reaction Kinetics

CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

MEETING—New York, N. Y.

Liquid Entrainment and Its Control

CHAIRMAN: H. E. O'Connell, Ethyl Corp., P. O. Box 341, Baton Rouge, La.

Absorption

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Centrifugation

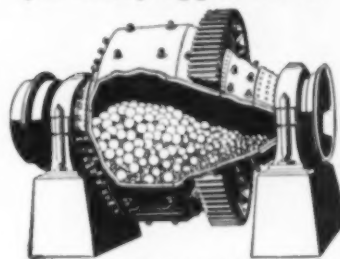
CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Nucleation Processes

CHAIRMAN: E. L. Piret, Dept. Chem. Eng., Univ. of Minn., Minneapolis 14, Minn.

Authors wishing to present papers at a scheduled meeting of the A.I.Ch.E. should first query the Chairman of the A.I.Ch.E. Program Committee, Loren P. Scoville, with a carbon copy of the letter to the Technical Program Chairman of the meeting at which the author wishes to present the paper. Another carbon should go to the Editor, F. J. Van Antwerpen, 120 East 41st Street, New York 17, N. Y. If the paper is suitable for a symposium, a carbon of the letter should go to the Chairman of the Symposia, instead of the Chairman of the Technical Program, since symposia are not scheduled for any meeting until they are complete and approved by the national Program Committee. Before authors begin their manuscripts they should obtain from the meeting Chairman a copy of the Guide to Authors, and a copy of the Guide to Speakers. The first book covers the preparation of manuscripts, and the second covers the proper presentation of papers at A.I.Ch.E. meetings. Presentations of papers are judged at every meeting and an award is made to the speaker who delivers his paper in the best manner. Winners are announced in *Chemical Engineering Progress*, and a scroll is presented to the winning author at a meeting of his local section. Since five copies of the manuscript must be prepared, one should be sent to the Chairman of the symposium and one to the Technical Program Chairman of the meeting, or two to the Technical Program Chairman if no symposium is involved and the other three copies should be sent to the Editor's office. Manuscripts not received 120 days before a meeting cannot be considered.

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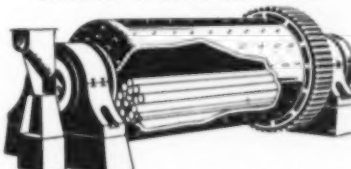
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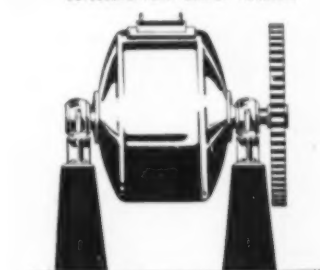
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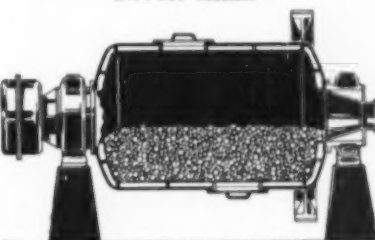
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LOCAL SECTION NEWS

(Continued from page 58)

The Ohio Valley Section held its May meeting on the fourth at the Engineering Society Headquarters in Cincinnati.

After the dinner a business meeting was held. Officers elected for the next year are: Ted Wiehe, chairman; Stanley N. Baechle, vice-chairman; Sven Englund, secretary; and Robert St. John, treasurer.

This was the annual student night when by custom the program consists of two papers presented by students at the University of Cincinnati. Raphael Katz presented a paper titled, "Mass Transfer in Fluidized Beds," and Isadore Coidas gave a paper "Measurement of Surface Temperature of Solids."

An all-day Symposium on Fat and Oil Industries was held at the Engineering Society headquarters in Cincinnati, Ohio, on April 24, 1953. The symposium was sponsored by the following local sections of A.I.Ch.E.: Ohio Valley, Akron, Cleveland, Central Ohio, and Pittsburgh, Pa. About ninety registered for the Symposium.

The papers, reported by N. W. Morley, were as follows:

THE SUPPLY AND THE CONSUMPTION OF OILS AND FATS by R. A. Duncan, associate director of chemical division, Proctor and Gamble Co.

TRANSESTERIFICATION OF FATS by L. J. Armstrong, assistant division manager, New Products, and A. Mudrak, group leader, organic department, The Horshaw Chemical Co.

SOME NEWER USES OF FATTY ACIDS AS BASIC RAW MATERIALS by Richard R. Egan, chief chemist, The Gerson-Stewart Corp.

REVERSION IN EDIBLE FATS AND OILS by B. F. Daubert, assistant manager, laboratory section, The Koppers Co.

RECENT ADVANCES IN THE UTILIZATION OF ANIMAL FATS AND OILS by Waldo C. Ault, head of the animal fat division, Eastern Regional Research Laboratory, U. S. Department of Agriculture.

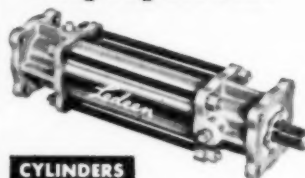
SOME PROCESS TRENDS IN THE FATTY OIL INDUSTRY by H. L. Barnebey, H. L. Barnebey Chemical Processes, Pittsburgh, Pa.

AN ELECTROLYTIC CELL FOR REGENERATION OF CHROMIC ACID by J. D. Fitzpatrick and R. P. Rolles, Emery Industries, Inc.

The thirty-ninth general meeting of the East Tennessee Section was held May 14, in the Library, research laboratories, Tennessee Eastman Co., with thirty-six members and guests present.

Howard Kehde, of the Union Oil Company of California, guest speaker, talked on the Hypersorption process for gas separation. Toy F. Reid, secretary-treasurer, reported that the talk was well received by the audience.

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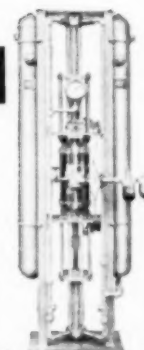
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The Western New York Section toured the Ford Motor Co.'s stamping division on May 28 and enjoyed both the trip and the roast beef dinner.

A meeting was held at the LaSalle Yacht club, Niagara Falls, on May 14. W. L. Faith, director of engineering, chemical division, Corn Products Refining Co., talked about process development in the food and agricultural industries.

James W. Casten, reporter, announced that this was the last formal meeting of the season.

Thirty-six members attended the dinner and approximately a total of forty attended the talk.

"Opportunities in Chemistry and Chemical Engineering" was the topic of a panel discussion held May 26, 1953, in the Jewett City High School auditorium by the Eastern Connecticut Chemical Engineers Club. Moderator of the panel discussion was L. W. Bass, director of industrial research, Arthur D. Little Co.

The Eastern Connecticut Chemical Engineers Club was founded about sixteen months ago to fulfill the need for a professional group in eastern Connecticut where chemical engineers and chemists might meet socially as well as to exchange scientific information.

Names of the officers of the club for 1953, as reported by E. W. Blase, chairman of the Publicity Committee, are: Norman Greenman, Rogers Corp., chairman, Ray Rosenfield, New England Chemical Works, vice-chairman, and Sol Elmasian, Plastic Film Corp., Sec.-Treas.

Frank L. Steakley was the speaker at a recent meeting of the Nashville Section. His subject was "Ion Exchange Resins." Bob Nance reports that Dr. Steakley is the director of the chemical technology division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Recent doings of the New York Section were reported by Bernard H. Rosen, publicity chairman. He referred to the talk given by D. R. Burtfield, Merck & Co., at the Brass Rail, Fifth Avenue, New York, on May 19. The subject was "Ten More Years of Life," which covered the large-scale manufacturing of antibiotics. At this meeting new officers were elected as follows:

F. White, chairman; R. Shaffer, vice-chairman; S. Adler, treasurer; W. T. Dorsheimer, secretary; and R. Morton, member-at-large.

The next meeting is scheduled for 12:00 noon on June 18 at the Brass Rail, Seventh Avenue, New York, when W. P. Gage, president of Grace Chemical Co., will discuss "From Ships to Chemicals," a "why-and-how" account of the W. R. Grace Co.'s entry into the chemical field.

Because of space limitations considerable material was held out of this issue.

—H.R.G.



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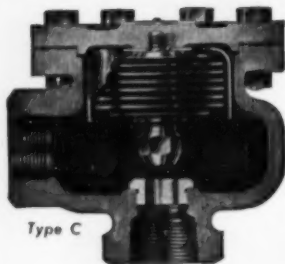
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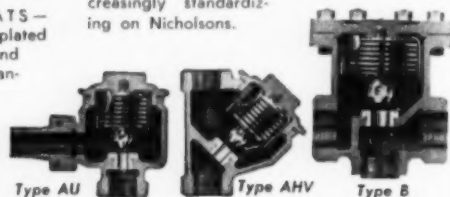
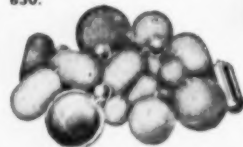
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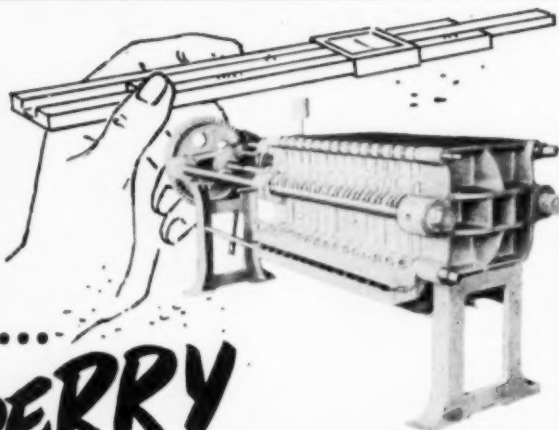
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PEOPLE

NEW APPOINTMENTS
BY WESTVACO

H. A. Sommers has been appointed chief engineer by the Westvaco Chemical Division of Food Machinery and Chemical Corp. Since joining Westvaco in 1950, Sommers has been assistant chief engineer with responsibility for the Intermountain Chemical soda ash plant development



at Green River, Wyo. A graduate of Case Institute of Technology, Mr. Sommers has been with Mathieson Chemical Corp. as project engineer and works manager for its magnesium-chlorine plant at Lake Charles, La., and, later, chief engineer and assistant to the vice-president, director of operations.

Robert J. DeLargey, formerly general assistant to the operating vice-president, has been appointed director of engineering. Prior to joining Westvaco in 1951, he was assistant general manager of Grove Regulator Co., Oakland, Calif., and former superintendent of Shell Chemical's ammonia plant in Pittsburg, Calif. He is a chemical engineering graduate of Case.



Gordon A. Cain, on the general development staff of Westvaco Chemical Division, has been promoted to general assistant to the operating vice-president, W. N. Williams. Mr. Cain is a chemical engineering graduate of Louisiana State University, and has been associated with Freeport Sulphur, and Merck & Co. Previous to joining Westvaco in 1951, he was engaged in chemical consulting work.



Harold G. Donnelly, formerly professor of chemical engineering, has become head of the chemical and metallurgical engineering department of Wayne University.

Harry P. Donohue has recently been taken into the firm of Godfrey L. Cabot, Inc., Boston, Mass. He will be working in the applications research and technical service section. Donohue received his B.S. degree from Tufts College.

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Robert E. Siegfried and William D. McDonough have recently been added to the process engineering group of Badger Manufacturing Co., Cambridge, Mass. His previous experience in process and project engineering for E. B. Badger & Sons Co. was in Boston and E. B. Badger & Sons, Ltd., in



R. E. Siegfried



W. D. McDonough

Great Britain. Prior to Mr. McDonough's association with Badger, he was with Lederle laboratory division of American Cyanamid Co. and chemical plants division of Blaw-Knox Construction Co. engaged in work on vegetable oil extraction, solvent recovery and coal-tar processes.

AARON ROSE WINS FULBRIGHT FELLOWSHIP

Aaron Rose, associate professor of chemical engineering at Washington University, St. Louis, Mo., and membership committee chairman for the St. Louis Section of A.I.Ch.E., has been awarded the Fulbright Fellowship to the University of Nancy, France, for the 1953-54 academic year. He will lecture in French on chemical engineering unit operations at the University of Nancy which was founded in the sixteenth century.

G. E. Evans, who has been in charge of production control at the Kobuta plant, Koppers Chemical Co., Inc., has been transferred to Pittsburgh to become assistant to the division production manager.

The F. J. Stokes Machine Co. has appointed J. William Robinson manager of its new Canadian branch in Montreal. From 1948 to 1951 Mr. Robinson was connected with the engineering division of Imperial Oil Limited, in Sarnia, Ont. From 1951 until he joined Stokes, he was with



Courtaulds (Canada) Limited, in Montreal, first as manager of its commercial intelligence unit, and later, in charge of sales development of industrial applications for rayon.

(More About People on page 65)

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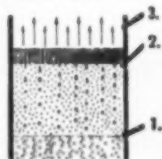
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PEOPLE

Henry H. Sineath has been appointed to the newly created position of assistant



to the director of Georgia Tech's Engineering Experiment Station, Atlanta, Ga. He joined the Station in 1951 and prior to his new appointment served as a research engineer in charge of a government-sponsored

project to determine industrial needs for raw materials derived from plants not native to the United States. His previous experience includes supervision of a pilot plant for International Minerals and Chemical Corp. and several years as post engineer at various U. S. Army Corps of Engineers installations.

Albert M. Stover, formerly manager of Marvinol plastics development, has been appointed assistant to the director of research and development of the Naugatuck Chemical division, United States Rubber Co. In his new assignment Mr. Stover will work principally on the development of new products. A graduate of Yale, Mr. Stover has been with Naugatuck Chemical since 1949. At Glenn L. Martin he had been director of development for the chemical division.

Cary R. Wagner is presently president of the Synthetic Organic Chemical Manufacturers Association of the United States. Dr. Wagner returned to private consulting practice in 1952 after he resigned as senior vice-president of General Aniline & Film Corp. Effective May 19, 1953, he resigned from the boards of General Dyestuff Corp., and General Aniline & Film Corp.

Food Machinery and Chemical Corp. has announced the appointment of

Franklin Farley as management consultant to its chemical divisions administrative staff in New York City. Mr. Farley's business experience includes service with Arthur D. Little, Inc., Cambridge, Mass., the Phosphate Mining Co., of which he was treasurer and in charge of operations, and for the past twelve years vice-president in charge of the phosphate division, International Minerals & Chemical Corp., Chicago, Ill.



(More About People and Necrology on page 66)

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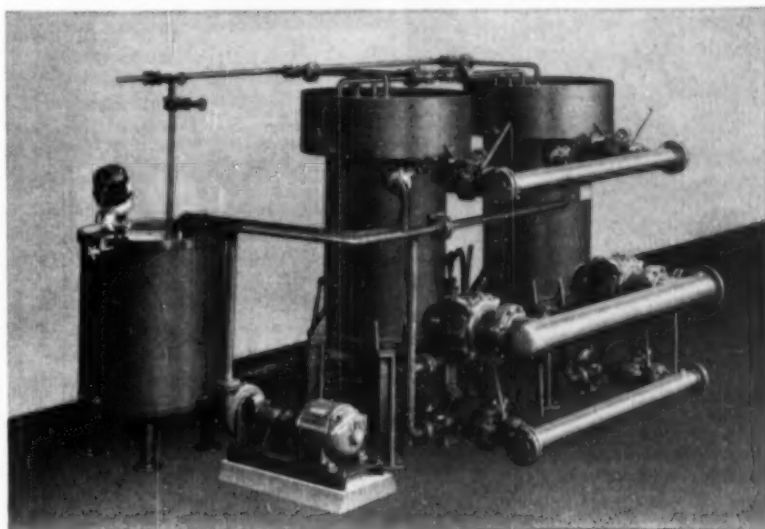
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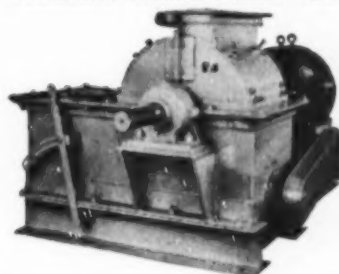
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Wendell W. Waterman, director of research and development, Morton Salt Co., Chicago, Ill., is now coordinating activities of the company's new research and development organization, which will expand research in the field of salt products and processes, and engage in chemical process development. Dr. Waterman held positions in the development and process engineering divisions of Standard Oil Development Co., Publicker Industries, and Rust Process Design Co. prior to joining Morton in 1952.

Arthur R. Broadman has recently been elected vice-president in charge of engineering and purchasing by the directors of the Heyden Chemical Corp. He has been assistant vice-president in charge of engineering since 1948, and is a director of St. Maurice Chemicals, Limited. He joined Heyden's engineering division in 1939. From 1944 to 1945 he was production superintendent at Cherokee Ordnance Works, Danville, Pa., and from 1946 to 1947 he was production superintendent at Morgantown Ordnance Works, Morgantown, W. Va.

H. L. Hilleary, group leader, was appointed assistant superintendent of the laboratory in charge of general technical service, scheduling, and refinery economics work at Standard Oil Co. (Ind.). Mr. Hilleary became associated with Standard in 1947 as a chemical engineer.

J. E. Troyan has been appointed manager of process development, Mathieson Chemical Research and Engineering Division, Mathieson Chemical Corp., Baltimore, Md. He has been with Mathieson since 1949, first as director of experimental engineering and later as associate director of research and engineering at Niagara Falls, N. Y.

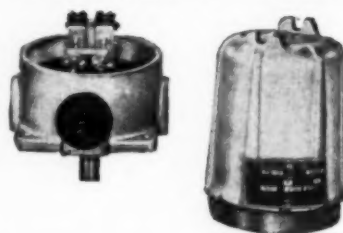
Necrology

Chemical Engineering Progress has recently heard of the death of the following:

Charles Fisher Ritchie, assistant technical director of the Uranium Project Division, Mallinckrodt Chemical Works. Mr. Ritchie, a graduate of California Institute of Technology in 1922, was with American Potash and Chemical Co. in Trona, Calif., for nearly twenty years before going to Mallinckrodt in 1945.

Laverne T. Heaps, manufacturing engineer, alkyl resin plant, General Electric Co., Schenectady, N. Y.

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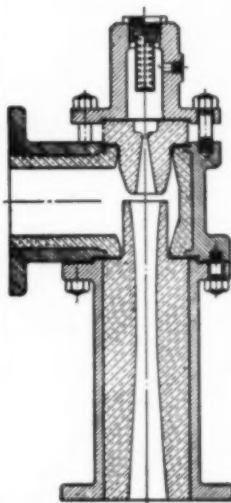
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THE PRESIDENT SAYS



... We have the Walker Award and the Professional Progress Award ...

A man who has been diligent and effective in the service of the Institute recently said that the members of A.I.Ch.E. ought to decide whether they are electing men to office in order to *get a job done*, or merely to *honor* these members. He points out the fact that each policy may bring into service entirely different individuals. This is true. For a variety of reasons men, whose contributions to the profession of chemical engineering are extremely significant, may not always make good Institute officers. They may by temperament wish to avoid the management duties, which are inescapable; or they simply may have professional responsibilities which prevent the unavoidable travel involved. At the present time, Institute affairs are of such a nature that much of the leadership is supplied by volunteer effort. In accordance with tradition, the paid staff of the Institute is engaged to carry out the plans made by the members. Indeed until the recent past any attempt on the part of the paid staff to furnish leadership to a significant extent would have been viewed with alarm by many members.

The A.I.Ch.E. is becoming so complex that we shall soon have to look to our paid staff for leadership and to carry out many of the projects now handled by volunteers from the membership. Just now we are in a transition period when we have many problems requiring attention, too many, in fact, for comfort and yet our budget will not stretch far enough to hire all the help we need. You should know, though, that Council is working on these matters and in time we shall come up with a worth-while solution. Meanwhile, we are keeping our Vice-President busy. He is no mere figure-head and he is working shoulder to shoulder with me in developing a program of accomplishment that will extend through *his* administration and beyond. Just as soon as we know whom you elect Vice-President for 1954, we shall get with *him* to continue this process of advance planning for sound practices and effective organization. Incidentally, you ought to be getting your thoughts in good order for the nomination ballot which will soon reach you.

• • • • •

I have run across a comment somewhere to the effect that Institute leadership (or professional society leadership—I forget which) is monopolized by people who

have the "management viewpoint," whatever that is. Assuming that this necessarily would be bad (which I don't believe) and assuming that this means people who are relatively high up in industrial organizations, it certainly isn't true in A.I.Ch.E. I have the Yearbook before me and, as I look at the names of those who have been officers or directors, I am sure no one could argue reasonably that any one viewpoint has been represented to the exclusion of all others. We have had people cutting across the entire scope of the profession in the high councils of our organization.

Anyone who has sat through many Council meetings must have been impressed with the fact that many and diverse viewpoints are represented and that no individual and no clique controls either Council or the A.I.Ch.E. I can tell you that the President gets his lumps from Council any time he gets off base, and I wouldn't have it any other way.

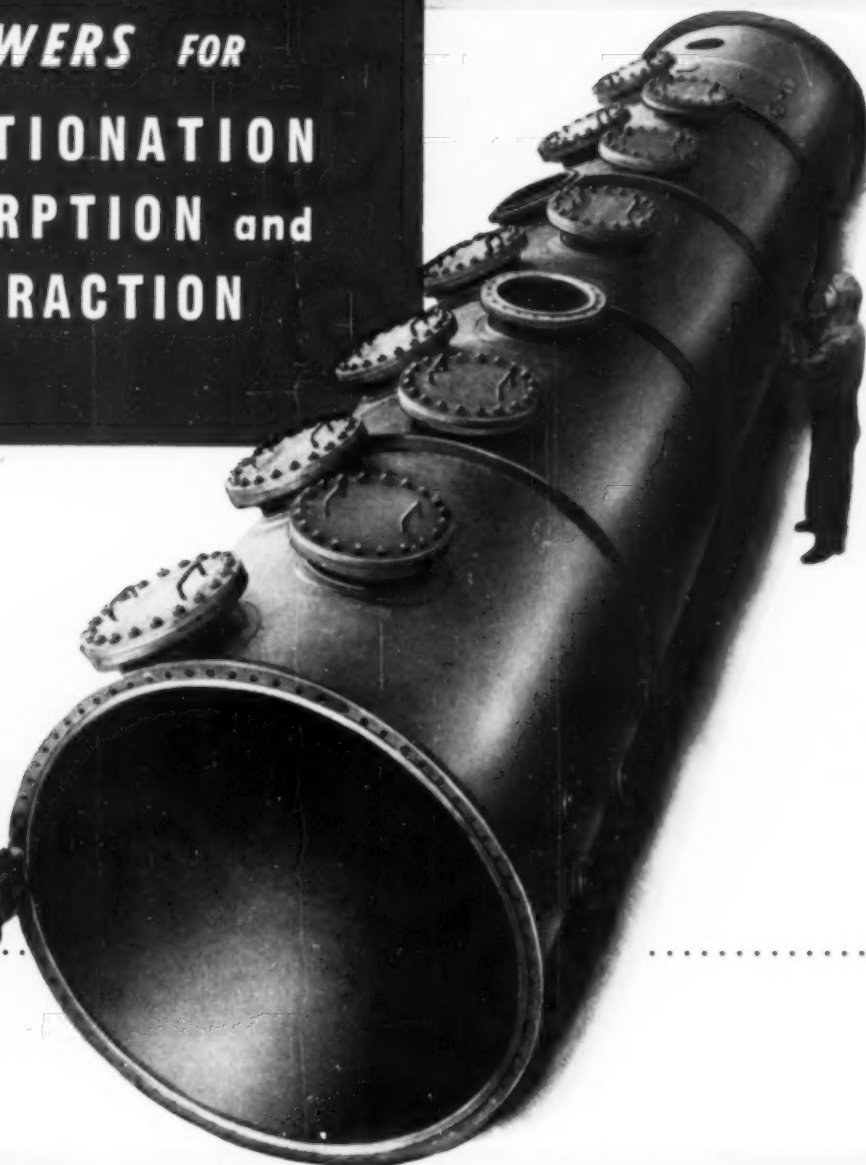
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Perhaps election to office isn't the best way to do honor to the chemical engineers who deserve to be honored, anyway. We have the Walker Award and the Professional Progress Award, for example, and the opportunity to nominate some of our members for the Perkin Medal Award. There has been some talk, from time to time, about establishing some sort of Academy of Chemical Engineering to which eminent chemical engineers could be elected in order to recognize their professional achievements. When I observe the professional accomplishments of some of our members who do not seem ever to be considered for Institute offices, I feel extremely humble and wish there were other tangible ways to bring distinction to these men. To be truthful, I do not believe some of these men would be especially interested in serving as officer or director. I would welcome suggestions for some new ways to recognize and signal the great work being done by chemical engineers in the advancement of chemical engineering in theory and in practice.

I believe my friend was right. We ought to take thought whether we are electing men to *honor them*, or to *get a job done*.

W. J. Nichols

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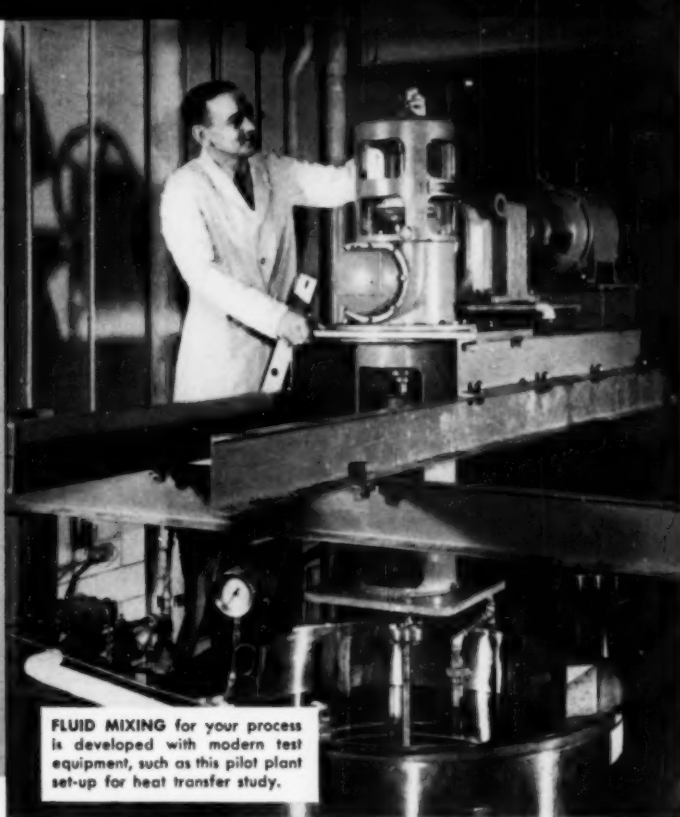


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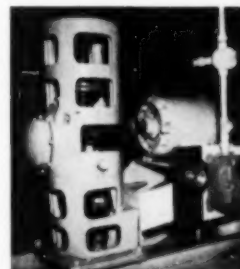
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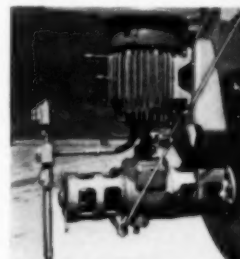
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